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EVALUATION OF FOUR RECENT TRAFFIC AND SAFETY INITIATIVES

Volume IV: Increasing Speed Limit Compliance in Reduced Speed School Zones

FINAL REPORT

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UDOT RESEARCH & DEVELOPMENT REPORT ABSTRACT

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16. Abstract

Reduced speed school zones greatly improve the safety of young children commuting to and from school and provide more appropriate gaps in traffic for children to cross the street. The safety and efficiency of a school zone depends on drivers' compliance to the school zone speed limit. The main focus of this study was to determine effective methods for increasing speed compliance in reduced speed school zones. This objective was accomplished through an in-depth literature review, a public opinion survey of Utah drivers, and a before and after evaluation of the effects of speed monitoring displays (SMDs) in four different school zones in the state of Utah.

The literature review concludes that a combination of effective traffic controls, public education, and appropriate law enforcement are all necessary to improve speed limit compliance in school zones. The results of the public survey produced similar results. The drivers surveyed felt that there is need to improve school zones safety in the State of Utah through education, more effective traffic control devices, and increased law enforcement.

The field study found that the SMDs analyzed proved to increase speed compliance in most cases. In some cases, the SMDs maintained their effectiveness at increasing speed compliance; on the other hand, some gradually lost some of their effectiveness. The distribution of speeds at essentially every location demonstrated a reduction in excessive speeds. For the most part, these SMDs helped improve school zone safety by decreasing speeds and increasing speed compliance as manifested by the decrease in mean speed, standard deviation, 10 mph pace range and the percentage of vehicles exceeding the 20 mph school zone speed limit.

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NOTICE

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1 Introduction

For years, traffic engineers and other roadway officials have provided young children with safe havens for crossing the street on their way to and from school. These safe havens are referred to as school zones and consist of a wide variety of traffic controls such as signage, flashing beacons, crossing guards, etc. School zones are used to increase drivers' awareness of the presence of children crossing the street. At times traffic engineers must reduce vehicular speeds in these zones to provide safe and adequate gaps in traffic for the children to cross the street without harm. A number of methods for reducing speeds in school zones have been implemented with some being more effective than others. A challenge that traffic engineers must face is determining which method will be the most effective at increasing and maintaining speed compliance in reduced speed school zones.

This report discusses the effectiveness of different procedures and methods of reducing speeds in school zones. An in-depth literature review was performed to determine what has been done and what is the most effective. A public survey was conducted among Utah drivers to find out their opinions and views about current traffic controls in school zones, as well as to assess their attitudes and feelings toward specific school zone traffic controls. By understanding drivers' attitudes and opinions, traffic engineers can appropriately decide which controls should be used to produce the most efficient result. In addition, speed monitoring displays (SMD) were installed in four reduced speed school zones in Utah in order to evaluate the effectiveness of these dynamic signs at improving speed compliance. Speed data collected from before and after the signs were installed were analyzed and compared. The results of the study can be found in the following chapters. This report discusses and explains the results of the literature search, public survey, and before and after speed analysis.

Chapter 2 Goals and Objectives

This study was commissioned by the Utah Department of Transportation (UDOT) to gain more information about the effectiveness of school zone traffic control devices used by UDOT for increasing speed limit compliance in reduced speed school zones. The main goal of this study is to enhance the safety of children commuting to and from school by increasing speed compliance in school zones.

The first objective of this study was to compile and evaluate past techniques for improving speed compliance in school zones through an extensive literature search. The next objective was to prepare and execute a public opinion survey about current school zone traffic control procedures to evaluate and better understand drivers' opinions and attitudes. The third objective of this study was to evaluate effects of SMDs in school zones with respect to drivers' speeds.

Chapter 3 Methodology

This research project consists of three main components. The first component is an in-depth literature search on increasing speed compliance in reduced speed school zones. The second involves the execution of a public opinion survey with respect to school zone safety and speed compliance. Last, but not least, the project in entailed an evaluation of SMDs in four school zones in the state. From the findings of these three components, a set of recommendations were developed with regards to school zone safety and efficiency.

3.1 Literature Review

The main focus of the literature review was to determine how to increase and maintain speed compliance within school zones. The uses of different school zone traffic controls such as flashing beacons, pavement markings, traffic signals, different speed limits, crossing guards and others were researched. An extensive search of the use and effectiveness of SMDs in school zones was performed. Other speed influences were explored as well, such as law enforcement, increased fines and traffic calming techniques. The literature review discusses the factors found to influence drivers' speeds in school zones and other findings that relate to school zone speed compliance.

3.2 Public Survey

A public opinion survey was designed and executed to determine the attitudes and behaviors of Utah drivers with respect to school zone safety and speed compliance. The survey consisted of 20 questions and was given to 762 drivers. The questions of the survey were specifically designed to determine drivers' opinions about the necessity to improve the safety and efficiency of school zones, the general speed compliance in school zones, any apparent speed influences, and the effectiveness of SMDs. An additional analysis of the data was performed to find any apparent relationships between the way any two questions were answered. These relationships were found using a Chi-squared test to see how the actual frequency of responses differed from what was expected. By understanding the attitudes and behaviors of drivers, traffic engineers can provide the public with safer and more efficient transportation.

3.3 Field Study

A field evaluation of SMDs purchased by the UDOT was performed to determine if they improve speed compliance in school zone both in the short term and the long term. Four school zones were chosen by UDOT officials in which to install the new SMDs. The initial intent was to collect speed data before, about one to two weeks after, and again five to six months after the signs were installed. Unfortunately, that time table was not strictly enforceable due to problems with the SMDs not working properly. Regardless of these difficulties, speed data were collected in all four locations once the SMDs were working properly. Speed data were collected using Timemark road tubes provided by the UDOT. Data were collected for approximately four days (Monday through Thursday) for each condition (before, short-term, and long-term). Only speeds collected when the school zones were active were analyzed. From the data, statistics such as the mean speed, standard deviation, 85^{th} percentile speed, percent exceeding the school zone speed limit, 10 mph pace, and the percent in the 10 mph pace were computed. The before and after mean speeds were compared using a Normal Approximation Test to find out if there was any significant difference between the different conditions. The distribution of speeds were also plotted and compared to observe any apparent differences between the different conditions. The results of the analysis can help transportation officials decide whether or not to continue using the new SMDs.

Chapter 4 Literature Review

For many years, reduced speed school zones have been used to protect and improve the safety of children walking to and from school. Since young children tend to lack proper experience in dealing with traffic, there is a need to provide them with safe areas for crossing the street. School zones are used to offer a safer environment for kids to travel to and from school. By reducing vehicular speeds in these zones, children can more accurately judge appropriate gaps in traffic that are suitable to cross the street. In addition, drivers can stop quicker, as well as be more observant of their surrounding. Reducing speeds provides more gaps in traffic that are safe for crossing the street. If an accident were to occur in a school zone, the severity of that accident would be reduced as a result of lower speeds. One study suggests that the probability of a fatal pedestrian accident is six times less likely to happen if the vehicles' impact speed is 23 mph (10 percent chance of fatality), as opposed to it being 28 mph (60 percent chance of fatality) (Anderson, McLean, Farmer and Brooks 1997). Reducing vehicular speeds in school zones enables children to commute safety to and from school. The main focus of this literature search is how to increase and maintain speed compliance within school zones. To accomplish this purpose, the following subtopics will be discussed in further detail:

- Traffic Control in School Zones
- Speed Monitoring Displays in School Zones
- Enforcement in School Zones
- Other Speed Influences

4.1 Traffic Control in School Zones

The use of school zones is not a new concept. For years these reduced speed zones have been used to improve safety for young students. A number of traffic control measures have been used to slow vehicles down and thereby provide adequate gaps in traffic for students to safely cross the street. Some of these controls have been found to be more effective than others; however, the effectiveness of any traffic control method is conditional on the location where the control is being implemented. Specific findings of using traffic controls such as flashing beacons, pavement markings, traffic signals, different speed limits, crossing guards and signage are discussed below.

4.1.1 Flashing Beacons

Flashing beacons have been used for many years to make drivers more aware of the reduced speed limit in school zones. Many studies have reported that flashing beacons reduce speeds in school zones. However, there have been a few instances reported where flashing beacons were not very effective at reducing speeds. Flashing beacons make drivers more aware of school zones and remind them to reduce their speed to assure children's safety.

Zegeer, Havens, and Deen (1976) reported that "speed reductions attributable to flashers were statistically significant at the 95 percent level at 84 percent of the locations; the average speed reduction was 3.6 mph." The authors of this study also mentioned that there was a drop of about 5 mph in the 85th percentile speed for all 48 locations; however, they observed that the 85th percentile speed for all the locations was still about 19 mph over the 25 mph speed limit. A lack of sight distance between the motorists and the flashers may have been the cause for the ineffectiveness of the signs at five locations. Other possible reasons for the ineffectiveness of the flashers in this study included signalized or stop-sign intersections adjacent to or between the flashers, excessively long flashing times, and recent history of inappropriate flashing. For the most part, the flashers were effective at reducing speeds; however, they may have been more effective with a combination of other traffic control measures, for instance more law enforcement.

Reiss and Robertson (1976) also found that "there was a statistically significant decrease in speed when the sign was flashing as opposed to when it was not." The researchers randomly collected speed data with a radar gun. Once the speed was recorded for each vehicle, a police officer stopped each car downstream of the school zone to collect the drivers' opinions about the effectiveness of the flashing beacons. Reiss and Robertson concluded that drivers were generally not observant of the school advance warning and crosswalk signs. In fact, the majority of the drivers only noticed the active school zone sign with flashing beacons. Still, only 59 percent of those surveyed noticed the sign with the flashing beacons. Unfortunately, recognition of having noticed the flashing beacons did not always modify the drivers' behavior.

Burritt, Buchanan, and Kalivoda (1990) discussed a study to evaluate the effectiveness of flashing beacons in two school zones along a state highway. Prior to this study, the Arizona Department of Transportation (ADOT) had never installed flashers in school zones along state highways. ADOT's standard at the time was to install flashers on arterial streets within Tucson, but not on state highways. ADOT performed a study in 1987 to see if flashers should be installed in the two previously mentioned school zones along a state highway. The study recommended that flashers should not be installed. Despite this recommendation, the flashers were installed and evaluated to determine their effectiveness at reducing speeds. Unexpectedly, a statistically significant increase in the average speed was observed after the flashers were installed. The researchers measured a 4.2 and 1.9 mph increase in the average speed at the two locations analyzed. The results of this study concluded that flashing beacons were not an enhancement to school zone safety and could actually make conditions worse.

Sparks and Cynecki (1990) published a literature search of their own about the effectiveness of flashing beacons. They concluded from their search that flashers were ineffective at reducing vehicular speeds. "The longer the flasher operates, the more it becomes part of the scenery and eventually loses any effectiveness." Their search did not cite any studies where flashers were found to be effective. However, the search did bring to light the importance of avoiding overuse of flashers and maintaining uniformity to improve the effectiveness of flashers in school zones.

Hawkins (1993) discussed the results of a study performed in Iowa school zones along multilane roadways. Due to the size of the roadways, speeding through these zones was a problem. The approach speed limit to these school zones was 35 mph. Before and after speed spot studies were conducted at seven locations. Flashing beacons with oversized speed limit signs were tested and proved to significantly reduce vehicle speeds even a year after installation. These reductions in miles per hour were considered to be marginal (after one year, an 8.8 percent reduction of 2.8 mph in the afternoon, and a 5.6 percent reduction of 1.7 mph in the morning). The author also suggested the need for enhanced police enforcement, public awareness and public acceptance of the signs. These three factors could have contributed to the effectiveness of the signs in this study.

Aggarwal and Mortensen (1993) found advance school flashers to be effective at reducing speeds in a brand new school zone in northern California. Flashers were placed on a roadway where the normal posted speed limit was 40 mph. The results of the study definitely showed that flashers were effective in reducing vehicle speeds when the flashing beacons were on as opposed to when they were off. "The average speed reductions were from 38 mph to 31 mph, which is substantially closer to the goal of 25 mph." The total speed reductions may or may not be completely attributed to the flashers since multiple enhancements were added at the same time as the flashers (i.e. standard signing and pavement markings, and crossing guards). A before and after analysis may have produced more meaningful results, as opposed to comparing speeds when the signs were on to when they were off. The flashers coupled with crossing guards and other school zone pavement markings proved to reduce speeds and to make drivers more aware of the need to slow down in school zones.

Saibel, Salzberg, Doane, and Moffat (1999) reported on a study performed by the Washington Traffic Safety Commission (WTSC) to verify what types of school zone signs were most effective at causing speed limit compliance. Researchers conducted spot speed studies at 40 different school zones and concluded that if the approach speed limit was about 35 mph (30 to 40 mph), then the most efficient sign was the "When Flashing" one. The percent of vehicles exceeding 35 mph can be seen in Table 4-1 below for the different school zone signs examined in the study. The study also concluded that the type of sign had no significant effect on speeds for school zones with an approach speed limit of 25 mph. Reduced speed school zones with an approach speed limit of 35 mph should definitely be equipped with flashing beacons.

Table 4-1: Percent of Vehicles Exceeding 35 mph for Different Sign Types for School Zones with an Approach Speed Limit of 35 mph

Type of Sign	When Flashing	When Children Are Present	When Flagged
Percent Exceeding 35 mph	3.43%	29.93%	22.96%

(Source: Saibel et al 1999)

Flashing beacons are commonly used in reduced speed school zones on state routes in Utah. Although flashers may not be 100 percent effective at reducing speeds, they do improve driver awareness and provide safer environments for young students to cross the street. The general consensus of these studies is that proper use of flashers (avoiding excessive flashing periods, demonstrating uniformity and providing adequate enforcement) increases their effectiveness. For the most part, flashing beacons have proven to be an excellent addition to traffic control in school zones.

4.1.2 Pavement Markings

The Utah Department of Transportation (UDOT) (2003) produced a publication entitled *Traffic Controls for School Zones.* This document is based on the most recent addition of the Manual of Uniform Traffic Control Devices (MUTCD 2003) and discusses the current standards and recommendations for traffic controls in UDOT school zones. This document includes a section about school zone pavement markings. Typical pavement markings found in school zones include crosswalks, stop bars or yield lines, curb markings, large letters and/or symbols, and lane markings. All of these markings can be useful for enhancing the visibility of a school zone.

UDOT (2003) has reserved longitudinal crosswalk markings for school crosswalks and reduced speed school zones. Setting this standard preserves the uniformity of traffic controls in UDOT school zones. The Oregon Department of Transportation (ODOT) (2005) discourages the use of colored and/or textured crosswalks. ODOT claims that textured crosswalks tend to be less visible and require more maintenance. Since these crosswalks sometimes become considerably rough and can cause pedestrians to trip and fall in the middle of the street. The standardization of crosswalk pavement markings in school zones further distinguishes these crossings as a school zones.

According to the MUTCD, stop and yield lines are used in school zones to indicate the point where a yield or a stop is intended or required (MUTCD 2003). The use of these markings provides another warning to drivers of the presence of a school zone. Stop and yield lines are not required traffic controls for school zones, but can be used to more effectively attract drivers' attention than without them.

When parking regulations are in place, the use of a sign along with curb markings should be used in areas where snow and ice accumulation cover the curb (MUTCD 2003, UDOT 2003). Restricting parking near school crossings provides better sight distance for both pedestrians and drivers. The absence of parked vehicles also provides better visibility of the school zone signage.

Pavement Markings play an important role in controlling traffic in school zones. If properly implemented, pavement markings can make school zones more recognizable to drivers and thereby improve safety. Unfortunately, these markings can lose their effectiveness fairly rapidly. For example, they can be covered by snow, or might not be as visible when wet. Another limitation is that they must be repainted often since they tend to fade due to traffic and weather. When functioning properly, pavement markings make school zones more visible, and therefore effectively improve safety.

4.1.3 Traffic Signals

Sometimes, the public feels that installing traffic signals is the best thing to do to enhance safety. The solution is not always that simple. The truth is traffic signals may actually make some situations worse. Lee and Bullock (2003) prepared a study for the Indiana Department of Transportation to analyze crash data at seven traffic signals in or near school zones "that were installed where the warrants were justified by only a slim margin." The results of the study showed no benefit for installing traffic signals in school zones when the warrants defined in the MUTCD have not been met. The authors concluded that for intersections not meeting the warrants, signals should not be installed. In fact, the researchers did not find one significant safety improvement after installing the signals at all seven intersections in or near school zones. Lee and Bullock suggested that speeds in school zones could be reduced through two methods, driver awareness and enforcement. The authors also suggested that cities and county school districts prevent future schools from being built on major streets in order to improve pedestrian safety. Unless warranted and deemed necessary, traffic signals should not be installed in school zones to improve safety.

4.1.4 Speed Limits

Reduced speed school zones with higher approach speed limits require more traffic control than do school zones with lower approach speed limits to assure speed limit compliance. Saibel, Salzberg, Doane and Moffat (1999) found that the speed of vehicles in reduced speed school zones (20 mph speed limit) was much greater on roads with approach speed limits of 35 mph than they were on roads with a normal speed limit of 25 mph. Greater effort must be put forth in order to guarantee better speed compliance for reduce speed school zones with high approach speed limits.

Speed compliance can be achieved through better signage and regular law enforcement. According to a study in Nebraska, McCoy and Heimann (1990) concluded that on roads with a speed limit of 35 mph or higher, the most effective reduced speed limit within school zones was 25 mph. The researchers found that the 85th percentile speeds in school zones with an approach speed limit of 35 mph were actually lower with a school zone speed limit of 25 mph as opposed to speed limits of 20 and 15 mph. However, after a deeper look at the school zones analyzed in the study, practically all of the reduced speed school zones with 25 mph speed limits were equipped with flashing beacons. None of the reduced speed school zones with speed limits of 20 and 15 mph operated with flashing beacons. For this reason, it may not be appropriate to conclude that a reduced speed limit of 25 mph is the most effective speed limit. The reason the 85th percentile speed for these school zones was lower may be accredited to the flashing beacons or any other unknown variables. Proper signage and regular enforcement should be used to increase speed compliance in school zones. Uniformity of reduced school zone speed limits may also improve drivers' observance of the speed limit.

4.1.5 Crossing Guards

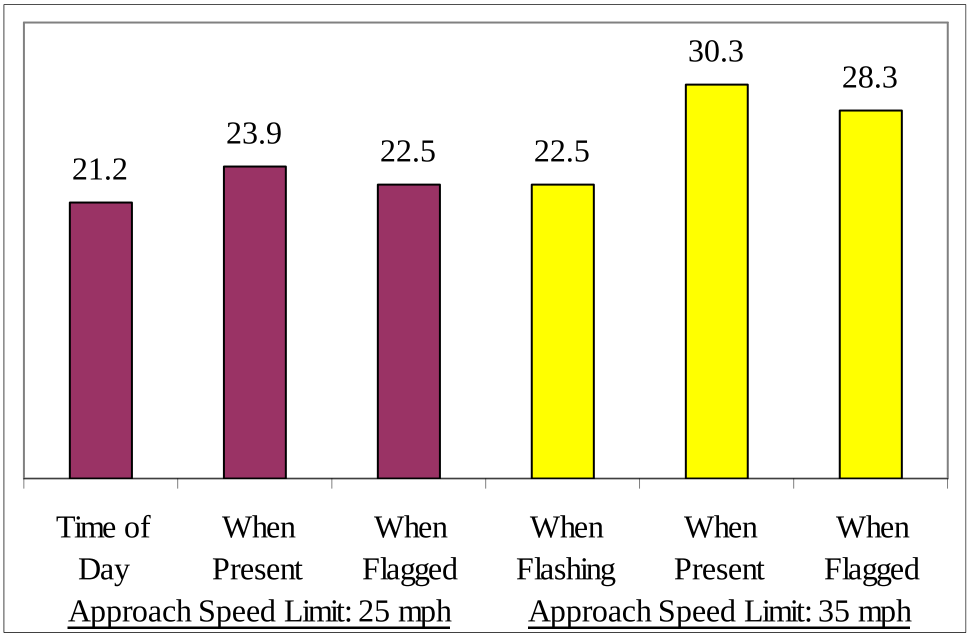
Although somewhat costly compared to other traffic controls, crossing guards considerably help reduce speeds in school zones. These generous individuals assist students by choosing appropriate gaps in traffic to stop vehicles so children can safely cross the street. Crossing guards should teach the young children safe crossing techniques and pedestrian safety (UDOT 2003). A study performed by Zegeer, Havens, and Deen (1976) found that the presence of crossing guards contributed to about a 9 mph drop in speeds at five different school zones. At the same locations without the presence of crossing guards, the average speed reduction was only 2.7

mph. McCoy, Mohaddes, and Haden (1981) also reported a speed reduction due to crossing guards. They observed that the presence of crossing guards reduced vehicular speeds by about 2 to 5 mph. Crossing guards definitely aid in reducing speeds and protecting children from unwanted accidents.

4.1.6 Signage

Just like any traffic control, signs should demonstrate uniformity to simplify the task of driving and to help drivers recognize and understand the warnings that are being presented. For this reason, it is important to determine which signs are the most effective at catching drivers' attention.

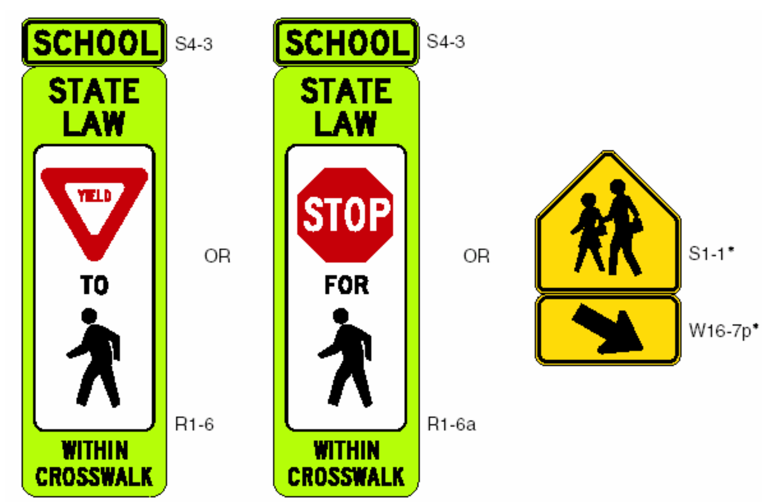
A study by Saibel, Salzberg, Doane, and Moffat (1999) helped verify what types of school zone signs were most effective. Spot speed studies were conducted at 40 different school zones in the state of Washington. The study concluded that if the approach speed limit of the road was 25 mph, then the type of school zone sign had no significant effect on vehicle speeds. The study also found that if the approach speed limit was about 35 mph (30-40), then the most efficient sign was the "When Flashing" one. The average speeds for school zones with different signs and approach speeds can be seen in Figure 4-1 on the next page. As mentioned earlier, school zones with an approach speed limit of 35 mph should definitely be outfitted with flashing beacons.



(Source: Saibel et al 1999)

Figure 4-1: Average Speed in School Zones vs. Sign Type and Approach Speed Limit

The use of in-street signs (Figure 4-2) can also make school zones more noticeable to drivers. The use of these signs should conform to the guidelines and standards outlined in the MUTCD. These signs are not required, but can be used to make school zones more noticeable (MUTCD 2003).



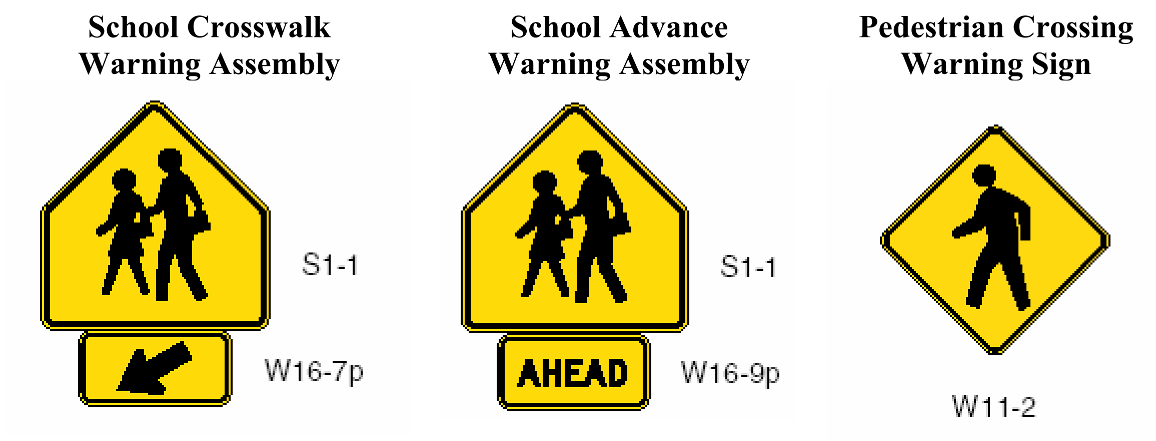
*Reduced Size – (Source: UDOT 2003)

Figure 4-2: In-Street Signs for School Zone Crosswalks

Redmon (2003) summarized a study that was performed using focus groups to assess the attitudes of both drivers and pedestrians. When using focus groups, researchers cannot generally guarantee any kind of statistically significant result; however, focus groups can be useful to assess attitudes and behaviors. Researchers found that those in the focus group of drivers felt that signs in the middle of street were effective at making drivers in general more aware of the law to yield or stop for pedestrians. Kamyab (2003) assessed the effects of in-street signs at a rural pedestrian crossing (not in a school zone) and found that in-street signs were effective at reducing average speeds by about 5 mph and increasing speed compliance by about 24 percentage points. When wisely implemented, in-street signs can compel drivers to slow down in school zones.

Another method of making school zone signage more visible to drivers is by using the newer fluorescent yellow-green (FYG) background on all school zone signs. UDOT has reserved the FYG background for school zone signs (UDOT 2003). The purpose behind doing this is to maintain uniformity of the signs, while making school zones more visible to passing drivers. A group of researchers in Canada performed a study of the effects of the FYG background at pedestrian crossings. They concluded that FYG pedestrian signage did not produce any detectable safety benefit. The mean percentage of motor-vehicle and pedestrian conflicts and the mean percentage of drivers yielding to pedestrians remained the same when comparing signs made with the FYG background to signs with a traditional white background (pedestrian signs in Canada are regulatory signs, hence the white background) (Van Houten, McCusker, Huybers, Malenfant and Rice-Smith 2002).

One problem with the current school zone signage is that it is very similar to the current pedestrian crossing signs. Even though they are different shapes and have different figures (see Figure 4-3), drivers confuse the two signs. Ford and Picha (2000) found that teenaged drivers had difficulty distinguishing between school advance signs and pedestrian signs; they also confused school crossing signs for pedestrian signs. Perhaps there is a need to make school zone signs more unique to maintain consistency and efficiency.



(Source: MUTCD 2003)

Figure 4-3: Comparison of School Zone Signs and Pedestrian Signs

Effective traffic control in school zones is essential to providing safe and appropriate gaps in traffic for children to cross the street. Controlling traffic and reducing vehicular speeds widens gaps in traffic and improves safety. The effectiveness of traffic controls depends on location and individual circumstances; therefore, safety engineers must use their best judgment to assign suitable traffic controls in school zones. Flashing beacons have proven to be effective in many instances to reduce speeds and make drivers more aware of their surroundings. Although limited by weather conditions and require frequent maintenance, pavement markings also alert drivers of the presence of school zones. When not warranted by the MUTCD, traffic signals in school zones can actually decrease safety. Compliance to reduced speed zones can be met through proper signage and the presence of crossing guards. School zones demand appropriate traffic control and enforcement to provide safe crossing and maximize their utility.

4.2 Speed Monitoring Displays in School Zones

Another way of reducing speeds and making drivers more aware of school zones is to use Speed Monitoring Displays (SMDs). SMDs are signs that use radar to measure and display the speeds of approaching vehicles. As drivers view their speed displayed on a sign, they become more aware of their speed and of their surroundings. SMDs attract attention to the roadways' surroundings by portraying the notion of possible of danger ahead. Drivers decrease their speed due to a perceived risk of enforcement and due to their increased awareness of their actual speed. A number of studies have reported that SMDs enhance school zone safety and efficacy.

Rose and Ullman (2003) evaluated the effectiveness of SMDs in and near school zones, as well as at other speed problem locations. In a rural school zone, an SMD was placed next to the school zone speed limit sign. The approach speed limit to the school zone was 55 mph. Before and after speed data were collected 2200 feet upstream of the SMD (a control point) and at the SMD. Immediately after the sign was installed, the SMD proved to reduce the average speed from 44.5 to 35.3 mph, the percentage of vehicles exceeding the school zone speed limit (35 mph) from 95.3

percent to 34.1 percent, and the 85th percentile speed from 50 to 40 mph. These statistics were all measured directly adjacent to the SMD. Even after 4 months, the SMD proved to be effective at maintaining lower speeds. The average speed next to the SMD was measured to be 35.7 mph, the percent of vehicles exceeding the speed limit was 43.9%, and the 85th percentile speed was 42 mph. The SMD was extremely successful at increasing and maintaining speed compliance.

The same study (Rose and Ullman 2003) evaluated the effectiveness of two SMDs located in advance of a reduced speed school zone (35 mph). For the northbound direction, the sign was located about 1950 feet upstream of the school zone. For the southbound traffic, the sign was placed about 1100 feet upstream of the school zone. The school zone was located at a signalized intersection. The signs were placed in advance of the school zone in an attempt to slow down vehicles before they reached the zone. The signs were located where the speed limit was 45 mph and operated continuously since they were not located directly in the school zone. Speeds were measured directly adjacent to the SMDs. For the northbound direction, the average speed before the signs were installed was 55.2 mph. Immediately after the signs were installed the average speed was 51.8 mph. After 4 months, the average speed was still less than the before average and measured to be 53.8 mph. For the southbound direction, the average speed before the sign was installed was measured to be 47.7 mph. Immediately after installation and about 4 months after, the average speeds were 45.1 and 46.3 mph respectively. Unfortunately, data was not collected in the school zones to see if the signs had any significant effect on speeds there. There was, however, less of a reduction in speed for this scenario compared to when the

SMD was located in the school zone and only operated when the school zone was activated. This suggests that it may be more efficient to locate SMDs in the vicinity of a school zone rather than in advance of one. This also suggests that perhaps SMDs should be activated only during necessary time periods to avoid overuse.

Another evaluation of SMDs in school zones by the City of Garden Grove, California (2003) also found SMDs to be effective at reducing speeds in school zones. Four signalized school zones were equipped with SMDs that were mounted on either the signal mast arm (suspended over the street) or on the signal pole. Calculations were performed to determine the structural capacity of the mast arm to assure safety. Each school zone was outfitted with an SR4R 'School-25 mph-when children are present' sign that was located adjacent to the SMD. The SMDs were activated for two hours before and two hours after school. Researchers collected speed data before and after the SMDs were installed. The after results were measured about two to three months after installation. The before and after 85th percentile speeds determined by the researchers can be seen in Table 4-2 below.

Table 4-2: Before and After 85th Percentile Speeds for Different School Zones with SMDs Installed

Location (Street Name)	ADT	No. Lanes	Speed Limit	Before	After	Percent Change
Springdale	11,800	4	35	42.7	33.8	20.8%
Orangewood	9,200	2	35	33.4	30.9	7.5%
Trask	29,200	4	35	44	34.2	22.3%
Buaro	8,000	2	25	26.9	25.4	5.6%

(Source: City of Garden Grove 2003)

Not only were the SMDs effective at reducing speeds, but they were also very well accepted by the public, including the local police department, schools and parent organizations.

Casey and Lund (1993) discussed the effectiveness of SMDs on vehicular speeds in multiple locations. As part of this study, SMDs were tested at a number of sites, including five reduced speed school zones (25 mph speed limit). Speeds were measured using undetectable radar. The SMDs proved effective at significantly reducing vehicular speeds in school zones. Within the school zones studied, the signs were found to reduce the average speed by about 14 percent where the baseline average speed was 10 mph over the speed limit and by about 7 percent where the baseline average speed was about 5 mph over the speed limit. The before and after average speeds for the five different school zones were about 35 to 30 mph, about 30 to 28 mph, about 35 to 30 mph, about 28 to 26.5 mph and about 32 to 27 mph. SMDs were definitely effective at lowering speeds within school zones.

Bloch (1998) evaluated the effectiveness of using photo-radar and SMDs to lower speeds. SMDs and photo-radar both proved to reduce speeds by about 4 to 5 mph. The effectiveness of the SMDs increased with law enforcement. All of these methods were especially effective on "excessive speeds traveling 10 mph or more over the legal limit." The effects of the devices did not last very long after they were removed. As part of the study, a cost-effectiveness study was performed and found that the SMDs without law enforcement were by far the most cost-effective method to reduce speeds.

Pesti and McCoy (2001) tested the effectiveness of SMDs in a series of work zones along I-80 in Nebraska. As part of the study, three SMDs were placed within a 2.7-mile strip of roadway that consisted of two work zones, and were evaluated for a 5-week period. The SMDs proved to be effective at reducing the mean speed (3 to 4 mph reduction) and the 85th percentile speed (2 to 7 mph reduction). The signs were effective the entire time, and even had some residual effects after the signs were removed. The authors noted that the results may not have been the same in areas that have higher percentages of commuter traffic, assuming that commuters might become more accustomed to the signs.

In summary, SMDs are an effective and efficient tool for reducing speeds in school zones. These signs give drivers a perceived sense of law enforcement. They also make drivers more aware of their surroundings and of how fast they are actually traveling. Very little has been done to determine if SMDs maintain their effectiveness over a long period of time. However, SMDs have definitely proven to reduce vehicular speeds in school zones for short periods of time.

4.3 Speed Enforcement in School Zones

Enforcement of traffic laws is essential to assure obedience of such laws. Unfortunately, people sometimes fail to understand the purpose of traffic laws. For this reason, these laws are broken. Credible law enforcement must be used to provide drivers with a reason to slow down. Zegeer, Havens, and Deen (1976) found that "regular speed enforcement in school zones by police agencies caused average reductions of 8.4 mph at seven locations." The perceived risk of getting a ticket undoubtedly increases speed compliance in school zones.

4.3.1 Law Enforcement

Proper law enforcement is a necessity to maintain speed compliance in school zones. Redmon (2003) summarized a study conducted for the Federal Highway Administration to assess general attitudes of drivers and pedestrians. Focus groups were used to obtain an understanding of the differing opinions between drivers and pedestrians. Researchers found that the drivers in the focus groups all had the general attitude that when a police officer was near, they would slow down. Redmon went even further to say that "unfortunately, drivers were influenced more by the thought of getting a ticket than by endangering a life." The drivers in the focus groups also felt that reminders were necessary for drivers to remember the laws with respect to pedestrians in the roadway. They thought that drivers should be reminded of the laws regarding pedestrians upon renewing their licenses. Regular police enforcement seems to have a great impact on drivers' attitudes toward speeding.

Law enforcement is expensive compared to other traffic control means. Fortunately, once law enforcement officials have established their presence and credibility in a school zone, these officials need not patrol that zone as frequently. McCoy, Mohaddes, and Haden (1981) concluded that school speed zones were only effective when drivers felt that there was a need for caution and when the creditability of enforcement was perceived. They found that once law enforcement had established credibility, less enforcement was necessary to maintain compliance. They also concluded that the desired reduction in speeds at school crossings could not be achieved without credible law enforcement. Law enforcement is crucial to maintaining and promoting compliance of school zone speed limits.

4.3.2 Fines

Jones, Griffith, and Haas (2002) conducted a study for the Oregon Department of Transportation and the Federal Highway Administration to measure the effectiveness of using double fines in reduced speed zones. The study examined the use of double fines in areas such as work zones, school zones and other safety corridors. Double fines have been used in Oregon school zones since 1997, however actual use of double fine warning signs have rarely been used. Since signs indicating double fines were rarely used in school zones prior to this study, drivers did not commonly notice them when the signs were used. When the signs were noticed, they were effective at influencing drivers to change their speed. "Awareness of the applicability of double fines in school zones elevates the perception of the risk of traffic fines, traffic citations and higher insurance rates." Drivers will reduce their speed in school zones if they are aware that they will be issued double fines for speeding such zones. Since most people work hard for their money, they would prefer to hold on to it, as opposed to paying excessive fines. Educating the public about the risk of increased fines for speeding in school zones can improve speed limit compliance and therefore enhance safety in school zones.

4.4 Other Speed Influences

In addition to school zone traffic controls and law enforcement, other factors can influence drivers' speeds such as different traffic calming enhancements and the presence of pedestrians. Surely, anything that gives drivers a reason or perceived reason to slow down will reduce speeds. McCoy and Heimann (1990) suggested "speed in school zones is influenced by the normal speed limits and speed characteristics of the streets on which the zones were located than by the school speed limits." Changing geometric alignments, lane narrowing, speed humps and other physical changes to roadway can cause vehicles to slow down. Drivers must perceive a reason for slowing down in school zone, or they will most likely not slow down. By using multiple methods to slow vehicles, traffic engineers can influence a greater percentage of drivers to reduce their speed in school zones.

4.4.1 Other Enhancements

Physical changes to a roadway can give drivers a reason to slow down; however, the implementation of such changes can cause speed reduction during other time periods as well. The building of school on or near busy streets should be avoided to limit pedestrian-vehicle conflicts and to ease the act of slowing vehicles.

Other traffic calming techniques can be used to slow vehicles. Schrader (1999) evaluated the effectiveness of other less common school zone traffic control devices. Schrader tested the effectiveness of five of these school zone traffic control devices at five different school zones. The devices included fiber optic signs, spanwire-mounted flashing beacons, post-mounted flashing beacons, transverse lavender stripes, and large painted legends. He found that all of these devices caused at least a slight reduction in the 85^{th} percentile speed; however only one caused a statistically significant reduction. That one traffic control was the fiber optic sign. The fiber optic sign was blank when the school zone was not active, but displayed the school zone speed limit of 20 mph when the school zone was active. Perhaps these controls would have been more effective a different school zones. Traffic engineers must be creative and consider many factors when attempting to slow traffic.

4.4.2 Presence of Pedestrians

Two particular studies have found that the presence of pedestrians reduces speeds in school zones (McCoy, Mohaddes and Haden 1981; Zegeer, Havens and Deen 1976). When drivers see the presence of pedestrians, they become more aware of a possible conflict and therefore reduce their speed. Providing adequate sight distance between pedestrians and drivers is very important in order to increase safety. Pedestrians, especially child-pedestrians, should be taught to make themselves more visible to oncoming traffic to reduce the risk of unnecessary conflicts.

4.5 Chapter Summary

In summary, traffic engineers should use multiple forms of traffic control to guarantee better speed compliance. Traffic engineers should work together with law enforcement officers to increase speed compliance and therefore improve the safety and efficiency of school zones. Uniformity of traffic controls, effective and noticeable traffic controls, education and proper law enforcement are all necessary to assure drivers are compliant to the school zone speed limit.

Chapter 5 Public Opinion Survey

Traffic engineers must comprehend public opinion toward traffic control devices to ensure efficacy of such procedures. Engineers must interpret drivers' feelings and reactions toward traffic control devices to guarantee desired safety and order. A public survey was written and administered to evaluate the feelings and concerns of Utah drivers with respect to school zone safety and traffic controls. Questions of the survey were designed to decipher drivers' opinions and views about school zone safety to assist transportation professions in providing well-designed school zones for all. The survey was also designed to determine how well Utah drivers feel they comply with the school zone speed limit. Possible safety enhancements were also considered and evaluated. The results were analyzed and compared to come up with possible changes or enhancements that should take place in UDOT school zones. The survey was implemented in various locations throughout the state of Utah. The study focused on how to improve and maintain speed compliance in school zones.

5.1 Description of Questionnaire

The questionnaire was designed to evaluate the attitudes and opinions of Utah drivers toward school zones traffic controls and child pedestrian safety. The survey attempts to depict drivers' opinions about children's ability to safely cross the street. The survey also endeavors to determine speed compliance in school zones based on drivers' opinions. The drivers' views of their speed compliance will be compared to actual compliance measurements found in Chapter 6. Some of the questions of the survey are intended to establish the most significant factors influencing speeds in school zones. Drivers were asked to rank various school zone traffic controls based on how they influence their speed. In addition, a few of the questions of the survey were specifically related to speed monitoring displays. An attempt was made to determine drivers' attitudes toward improving school zones through better signage, enforcement and traffic control. The survey consists of two sides that can be seen in Figure 5-1 and Figure 5-2.

Public Survey: School Zone Safety

This is a **completely anonymous** survey conducted by BYU students to determine drivers' opinions of school zone safety measures. There are 20 short questions that take just a few minutes to answer. Completing this survey is voluntary. Please answer each question honestly. Participants must be at least 18 years old, or have parental consent.

1.) Gender: ☐ **Male** ☐ **Female**
Age: ☐ **16-17** ☐ **18-25** ☐ **26-35** ☐ **36-50** ☐ **Over 50**

2.) How often do you drive a motor-vehicle? *(Check one)*
☐ **a.) About everyday** ☐ **c.) Just a few times a month**
☐ **b.) A few times a week** ☐ **d.) Rarely**

3.) If you do ***not*** have school-age children, go to question 5. If you do, how do they most commonly get to and from school? *(Check any that apply)*
☐ **a.) They walk or ride their bike alone** ☐ **d.) They ride the school bus**
☐ **b.) They walk, but are escorted by an adult** ☐ **e.) They are driven by another person**
☐ **c.) They ride public transit** ☐ **f.) They drive themselves**

4.) What type of schools do your children attend? *(Check any that apply)*
☐ **a.) Preschool** ☐ **c.) Junior High/Middle School**
☐ **b.) Elementary School** ☐ **d.) High School**

5.) There is need for more child pedestrian education in schools. *(Circle one)*

Strongly Agree	Agree	Somewhat Agree	No Opinion	Somewhat Disagree	Disagree	Strongly Disagree

6.) The majority of young students understand how to safely cross the street. *(Circle one)*

Strongly Agree	Agree	Somewhat Agree	No Opinion	Somewhat Disagree	Disagree	Strongly Disagree

7.) In your opinion, how important is it that vehicles slow down in school zones? *(Circle one)*

Extremely Important	Important	Somewhat Important	Not Important	No Opinion

8.) What is the uniform speed limit for reduced speed school zones in Utah? *(Check one)*
☐ **a.) 15 mph** ☐ **c.) 25 mph**
☐ **b.) 20 mph** ☐ **d.) 30 mph**

9.) The majority of people comply with the school zone speed limit. *(Circle one)*

Strongly Agree	Agree	Somewhat Agree	No Opinion	Somewhat Disagree	Disagree	Strongly Disagree

10.) How often do you drive through a school zone during the reduced speed times? *(Check one)*
☐ **a.) More than twice in a day** ☐ **c.) A few times a week** ☐ **e.) Never**
☐ **b.) About once or twice a day** ☐ **d.) Rarely**

11.) I obey the speed limit in school zones... *(Circle one)*

Always	Most of the time	About 75% of the time	About half the time	About 25% of the time	Rarely	Never

12.) When you speed in school zones, approximately how much over the speed limit are you traveling? *(Check one)*
☐ **a.) 0 – 5 mph** ☐ **c.) 10 – 15 mph** ☐ **e.) over 20 mph**
☐ **b.) 5 – 10 mph** ☐ **d.) 15 – 20 mph**

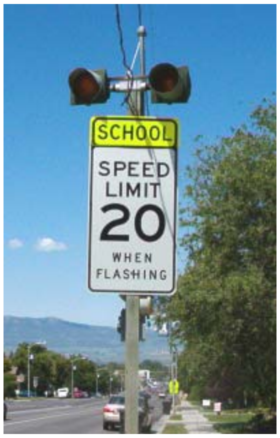
13.) If you have sped through a school zone before, what was the main reason for speeding? *(Check one)*
☐ **a.) You were not aware it was a school zone until it was too late.**
☐ **b.) You were in a hurry or late for something (for example, work or school).**
☐ **c.) You felt it was unnecessary to slow down due to absence of children.**
☐ **d.) You felt it was inconvenient to slow down, even when children were present.**

☐ **e.) Other** ____

(Continue on Back)

Figure 5-1: Front Side of Public Survey

14.)Rank the following factors from 1 through 5 (1 being the most influential) that influence your speed while driving through a school zone.



_____ Flashing Beacons above Speed Limit Sign *(Left)*

_____ Presence of children

_____ Presence of Law Enforcement

_____ Presence of Crossing Guard

_____ Police operated portable electronic signs that display drivers' speed *(Right)*

15.)How helpful are the electronic signs *(above right)* that display vehicle speeds at informing you of your speed while driving? *(Check one)*

☐ **a.) Very helpful** ☐ **c.) Sometimes helpful** ☐ **e.) Never helpful; I always know how fast I am going**
☐ **b.) Helpful** ☐ **d.) Rarely helpful**

16.)The electronic signs that display vehicle speeds are effective at making me aware that there might be danger ahead. *(Circle one)*

Strongly Agree	Agree	Somewhat Agree	No Opinion	Somewhat Disagree	Disagree	Strongly Disagree

17.)The electronic signs that display vehicle speeds are effective at causing me to slow down. *(Circle one)*

Strongly Agree	Agree	Somewhat Agree	No Opinion	Somewhat Disagree	Disagree	Strongly Disagree

18.)The new florescent yellow-green school zone signs help increase the awareness of the presence of school zones in comparison to the old yellow signs. *(Circle one)*

Strongly Agree	Agree	Somewhat Agree	No Opinion	Somewhat Disagree	Disagree	Strongly Disagree

19.)Were you aware that there are increased fines for speeding in school zones? *(Circle one)*

Yes **No**

20.)It is important and/or necessary to improve school zones (for instance, better signs, more traffic control devices, more law enforcement, etc.). *(Circle one and briefly explain)*

Strongly Agree	Agree	Somewhat Agree	No Opinion	Somewhat Disagree	Disagree	Strongly Disagree

What can be done? ____

____

Thank you for your time and for completing this survey!

If you have any questions about this survey, you may contact Dr. M. Saito at (801) 422-6326. If you have any questions regarding your rights as a participant in research projects, you may contact Dr. Renea Beckstrand, IRB Chair, BYU, 422 SWKT, Provo, UT 84602, (801) 422-3873, renea_beckstrand@byu.edu.

Figure 5-2: Back Side of Public Survey

5.2 Data Collection and Analysis

Once the survey was written, the data collection began. Other students were hired to assist in collecting data. The survey was administered in four areas throughout the state of Utah that are further described in the Survey Locations section below. The areas were consistent with the four school zones that would have the new speed monitoring displays added to them. Researchers collected surveys at public libraries and gas stations in these four areas. After completing the survey, those surveyed were offered a small compensation for their time (i.e. candy, soft drinks, etc.). The total number of surveys collected was 762. A wide variety of people were surveyed in the study as discussed in the Demographic Information section below.

5.2.1 Survey Locations

As mentioned earlier, surveys were collected in four general areas that were consistent with the location of the new speed monitoring displays. Logan was one of these areas. In Logan, surveys were collected as people entered and exited the Logan City Public Library and as people filled up with gas at the Chevron Gas Station on the corner of Main St. and 400 North. The second area where surveys were collected was in Salt Lake City. In Salt Lake, questionnaires were handed out at the Salt Lake City Main Public Library (400 South and 200 East) and at a Chevron Gas Station on the corner of 900 South and State Street. The third area was located in the City of Pleasant Grove, as well as in the City of Provo since they were very similar in nature. Data were collected at both the Pleasant Grove and Provo Public Libraries, and at a Chevron Gas Station on the corner of University Ave and 3700 North in Provo. The last area where surveys were gathered was in the City of Goshen and the City of Santaquin. These two areas were combined since they were very close to each other and were both located in a rural setting. In Goshen, surveys were collected as parents picked up their children from the Goshen Elementary/Middle School. In Santaquin, questionnaires were handed out as people filled up with gas at the Conoco Gas Station in the middle of town. All of these areas can be seen in the map below (Figure 5-3).

Figure 5-3: Map of Survey Locations

5.2.2 Demographic Information

Of the 762 people that were surveyed, 44 percent were male, 47 percent were female, and 9 percent failed to specify. Of those surveyed, there were 280 people between the ages of 16 and 25; 206 people were between the ages of 26 and 35; 160 people were between the ages of 36 and 50; and 91 people were over the age of 50. The rest (25 people) failed to specify what age group they were in. The survey was translated into Spanish in an attempt to determine any differences between the Spanish population and the English population. However, only 24 of the Spanish surveys were filled out. Seventy-nine percent of all of people surveyed said that they drive a motor vehicle about everyday. Seven percent only drive a few times a week, and three percent said they only drive a few times a month. Ten percent said they rarely drive (This seems to be more than would be expected. However, this high percentage is most likely attributed to a high number of transit riders surveyed at the Salt Lake City Public Library.) The results of the survey concluded that 36 percent of those surveyed had school-aged children, and 64 percent did not.

5.3 Drivers' Opinions

As mentioned earlier, the survey was designed to evaluate the driving public's opinions about school zone safety. Questions related to child pedestrians' ability to safely cross the street were evaluated to establish a need for school zones. Also, speed compliance was measured based on drivers' opinions. Factors influencing speeds in school zones were compared to determine the most effective traffic control for school zones. An effort was also made to determine drivers' opinions about speed monitoring displays in school zones. The main purpose of the survey was to find out exactly what the public thinks about improving school zones to provide students with a safe commute to and from school. The results of the survey will be discussed in further detail below. Please note that all the statistics presented below exclude missing responses; hence, the total number of respondents in the tables below may not add up to 762.

5.3.1 Children's Ability to Cross the Street

Drivers were asked whether they agreed or disagreed to two different statements with respect to how they felt about children's ability to safely cross the street. Table 5-1 below shows the number of people for each possible response to these two statements. The results to the first statement show that drivers feel there is a need to further educate young children in pedestrian safety (87.2 percent in the "agree" side). The results to the second statement were more spread out (65 percent in the "agree" side); however they still show that drivers were not very confident about young students' ability to safely cross the street. This suggests a need for more pedestrian education to young students. Parents, crossing guards, and teachers can and should be used to provide this education to these innocent children.

Table 5-1: Drivers' Feelings about Children's Ability to Cross the Street

Q1. There is need for more child pedestrian education in schools.						
Strongly Agree	Agree	Somewhat Agree	No Opinion	Somewhat Disagree	Disagree	Strongly Disagree
269 (35.5%)	306 (40.4%)	86 (11.3%)	77 (10.2%)	10 (1.3%)	4 (0.5%)	6 (0.8%)
Q2. The majority of young students understand how to safely cross the street.						
Strongly Agree	Agree	Somewhat Agree	No Opinion	Somewhat Disagree	Disagree	Strongly Disagree
33 (4.4%)	161 (21.2%)	299 (39.4%)	35 (4.6%)	136 (17.9%)	75 (9.9%)	19 (2.6%)

5.3.2 School Zone Speed Limit Compliance

Eighty-seven percent of the people surveyed felt that it was “extremely important” to slow down in school zones. Another eleven percent felt it was “important”. Not a single person said that it was “not important”. The majority of those surveyed (70.6 percent) were aware of Utah’s uniform speed limit for reduced speed school zones (Table 5-2). Still, almost 30 percent answered incorrectly. Perhaps drivers should be reminded of the school zone speed limit, as well as other traffic safety laws, every time they renew their license. The use of a uniform speed limit for reduced speed school zones may be the reason why the majority answered correctly. Uniformity eases the task of driving for all and can be the cause of higher speed limit compliance.

Table 5-2: Drivers' Knowledge of Uniform Speed Limit for Reduced Speed School Zones in Utah

Q8. What is the uniform speed limit for reduced speed school zones in Utah?			
15 mph	*20 mph	25 mph	30 mph
161 (21.2%)	537 (70.6%)	60 (7.9%)	3 (0.3%)

**Correct Answer*

Utah drivers seem to be very compliant to school zone speed limits. The results of three questions from the survey related to school zone speed limit compliance can be seen in Table 5-3. Opinions varied somewhat when asked if the majority of people comply with the school zone speed limit (only 56.3% in the “agree” side). However, when asked how they as individuals obey the school zone speed limit, most people claimed to be very compliant (91.4 percent responding with "always" or "most of the time"). Very few actually admitted to speeding in school zones. These results will later be compared to the actual speed limit compliance found in the four school zones discussed in Chapter 6.

Table 5-3: Survey Results on Speed Compliance in School Zones

Q9. The majority of people comply with the school zone speed limit.						
Strongly Agree	Agree	Somewhat Agree	No Opinion	Somewhat Disagree	Disagree	Strongly Disagree
21 (2.8%)	146 (19.3%)	259 (34.2%)	23 (3.0%)	155 (20.4%)	113 (14.9%)	41 (5.4%)
Q11. I obey the speed limit in school zones…						
Always	Most of the time	About 75% of the time	About half the time	About 25% of the time	Rarely	Never
493 (65.0%)	200 (26.4%)	38 (5.0%)	17 (2.2%)	5 (0.7%)	5 (0.7%)	1 (0.1%)
Q12. When you speed in school zones, approximately how much over the speed limit are you traveling?						
	0-5 mph	5-10 mph	10-15 mph	15-20 mph	Over 20 mph	
	628 (83.4%)	81 (10.8%)	27 (3.6%)	13 (1.7%)	4 (0.5%)	

5.3.3 Speed Influences

Another purpose of the survey was to determine what traffic controls and/or other factors have the most significant influence on drivers' speeds. When asked "If you have sped through a school zone before, what was the main reason for speeding?" in question 13, about 59 percent of the respondents (446 people) chose the response "You were not aware it was a school zone until it was too late". Whether this is the fault of the driver for simply not paying attention, or the result of insufficient traffic controls and warning devices, the answer is unclear. Perhaps both are to blame.

The next most popular reason for speeding in a school zone was that they (72 people or 9.4 percent) “felt it was unnecessary to slow down due to the absence of children”. These drivers could be deterred from speeding by avoiding excessive reduced speed time periods. In other words, a minimum time should be used when speeds are to be reduced to maximize roadway capacity and maintain the effectiveness of the school zone traffic controls.

Sixty-six people (8.7 percent) said their reason for speeding in a school zone was because they “were in a hurry or late for something”. Traffic engineers can do little to solve this problem. Law enforcement is most likely the best solution to cause these drivers to slow down in school zones.

The last reason for speeding on the survey was that people “felt it was inconvenient to slow down, even when children were present”. Fortunately, only 10 people out of 762 (1.3 percent) choose this answer. The attitude these drivers have is extremely selfish, and therefore makes slowing these drivers down very difficult for traffic engineers alone. Stricter fines and penalties for these drivers would hopefully cause them to increase their compliance to the school zone speed limit.

Another 105 people (13.8 percent) simply left this question blank for not having sped in a school zone before. The rest (63 people or 8.3 percent) marked “Other” and stated that either they do not speed in school zones, or they gave some other reason for speeding. Of the few other reasons for speeding mentioned by drivers, none stood out to the researchers as significant enough to document. Since the most common reason for speeding in school zones is that drivers are not aware of the reduced speed zone, more noticeable traffic controls should be used to grab drivers' attention.

As part of the survey, drivers were also asked to rank five different factors that influence their speed while driving through a school zone. The five factors included flashing beacons, the presence of children, the presence of law enforcement, the presence of a crossing guard, and speed monitoring displays. Those surveyed were asked to rank these factors from one to five with one being the most influential. For each factor, the number of drivers was counted for each specific rank (one through five), and the average ranking was then calculated. The results can be seen in Table 5-4. Only the surveys that properly ranked the factors from one to five were evaluated to avoid an unbalanced ranking of each factor. Five hundred and seventy-four people ranked the five factors as anticipated. The results after disregarding those who incorrectly ranked the five factors were actually very similar to the results before disregarding some of the surveys. The results to this question will be further discussed below.

Table 5-4: Drivers' Rankings of Factors Influencing Speed in School Zones

Flashing Beacons Above Speed Limit Sign						
Rank	1	2	3	4	5	Average Ranking
No. of Drivers	176	141	90	86	81	2.57
Presence of Children						
Rank	1	2	3	4	5	Average Ranking
No. of Drivers	244	163	89	44	34	2.06
Presence of Law Enforcement						
Rank	1	2	3	4	5	Average Ranking
No. of Drivers	89	132	90	155	108	3.11
Presence of Crossing Guard						
Rank	1	2	3	4	5	Average Ranking
No. of Drivers	32	100	234	141	67	3.19
Police Operated Portable Electronic Signs that Display Drivers' Speeds (SMDs)						
Rank	1	2	3	4	5	Average Ranking
No. of Drivers	33	38	71	148	284	4.07

As noted in the table, the most dominant factor influencing drivers' speeds is the presence of children. Hence, there is need to maintain adequate sight distance between drivers and pedestrians. Prohibited parking in school zones helps establish appropriate sight distance. Traffic engineers must provide adequate sight distance between pedestrians and drivers to assure safety and to reduce vehicular speeds.

The second most influential factor is the use of flashing beacons above the school zone speed limit sign. As mentioned earlier, flashers are effective at attracting attention to the presence of a school zone since they are only active when drivers should be more cautious. Flashing beacons are absolutely necessary for reduced speed school zones.

Drivers ranked the presence of law enforcement as the third most influential factor out of the five according to the average ranking. However, the most common rank given to the presence of law enforcement was fourth. Similarly, the ranking of the presence of crossing guards resulted in the fourth most significant factor according to the average ranking, but compared to other rankings, more drivers rated the presence of a crossing guard as the third most influential.

Surprisingly, SMDs were ranked as the least effective of the five factors. Drivers may have ranked the SMDs as the least effective since they have rarely been used in Utah school zones. Nevertheless, as will be discussed in further detail below, drivers feel that SMDs influence their speed and make them more aware of their speed and of their surroundings. Since SMDs were ranked the lowest and still prove to be effective, all five of the factors have great potential to significantly reduce speeds in school zones.

Driver awareness can help influence vehicles to reduce their speed in school zones. Recently UDOT has reserved the newer fluorescent yellow-green sign background for school zone signs to help set them apart from other signs and to maintain uniformity. As part of the public survey, drivers were asked if the new fluorescent yellow-green school zone signs help increase the awareness of school zones compared to the old yellow signs. The results to this question can be seen in Table 5-5 below. As noted in the table, most people (80.3 percent) agreed that the new signs were more effective at making school zones more visible to drivers than the traditional yellow signs.

Table 5-5: Effectiveness of Fluorescent Yellow-Green Background for School Zone Signs

Q18. The new fluorescent yellow-green school zone signs help increase the awareness of the presence of school zones in comparison to the old yellow signs.						
Strongly Agree	Agree	Somewhat Agree	No Opinion	Somewhat Disagree	Disagree	Strongly Disagree
176 (23.6%)	288 (38.6%)	135 (18.1%)	124 (16.6%)	13 (1.7%)	4 (0.5%)	7 (0.9%)

As noted in the literature search chapter of this document, increased fines have proven to be effective at reducing speeds. Utah currently penalizes drivers who speed in school zones with larger fines than enforced for speeding on other sections of roadway. Twenty-two percent of the drivers surveyed were not aware of increased fines for speeding in Utah school zones. These results suggest a need to educate Utah drivers about increased fines for speeding in school zones. As the perceived risk of increased fines and severer penalties is increased, speed conformity is enhanced and safety is improved.

Both improving traffic controls and increasing law enforcement enhance the safety and utility of school zones due to the reduction of vehicular speeds. Traffic controls and warning devices should be extremely visible to drivers. This enhanced visibility improves drivers' awareness, decreases speeds and augments safety. Law enforcement also gives drivers more reason to slow down. The combination of law enforcement and traffic control reduces speeds and supplements safety.

5.3.4 Effectiveness of Speed Monitoring Displays

As documented earlier in the literature search portion of this report, SMDs have proven to increase drivers' awareness of school zones and to reduce speeds. Various questions of the survey were designed to verify the public's opinion about the effectiveness of these signs. The results to these questions are found in Table 5-6. According to those surveyed, SMDs are very effective at increasing drivers' awareness of their surroundings and of their speed. The results also provide evidence that SMDs are effective at reducing speeds. SMDs caution drivers to reduce their speed in school zones by increasing their alertness of what is around them.

Table 5-6: The Effectiveness of Speed Monitoring Displays

Q15. How helpful are SMDs at informing you of your speed while driving?						
Very Helpful	Helpful	Sometimes Helpful	Rarely Helpful	Never Helpful; I always know how fast I am going		
335 (44.8%)	175 (23.4%)	132 (17.7%)	62 (8.3%)	43 (5.8%)		
Q16. SMDs are effective at making me aware that there might be danger ahead.						
Strongly Agree	Agree	Somewhat Agree	No Opinion	Somewhat Disagree	Disagree	Strongly Disagree
177 (23.6%)	240 (32.0%)	130 (17.3%)	67 (8.9%)	61 (8.1%)	52 (6.9%)	23 (3.2%)
Q17. SMDs are effective at causing me to slow down.						
Strongly Agree	Agree	Somewhat Agree	No Opinion	Somewhat Disagree	Disagree	Strongly Disagree
195 (26.0%)	301 (40.1%)	136 (18.1%)	27 (3.6%)	36 (4.8%)	37 (4.8%)	19 (2.5%)

5.3.5 Need to Improve School Zones in Utah

The last question of the survey asks drivers if they feel it is important and/or necessary to improve school zones through better signage, more traffic control devices and increased law enforcement. The results to this question can be found in Table 5-7 below. Without a doubt, Utah drivers feel there is a need for improvement with 89.8% of the respondents in the "agree" side. Utah drivers sense the need and importance of protecting young children from unwanted accidents. Providing better traffic controls and increasing law enforcement will reduce speeds and provide children with a safe commute to and from school.

Table 5-7: The Need to Improve School Zones in Utah

It is important and/or necessary to improve school zones (for instance, better signs, more traffic control devices, more law enforcement, etc.)						
Strongly Agree	Agree	Somewhat Agree	No Opinion	Somewhat Disagree	Disagree	Strongly Disagree
268 (35.9%)	291 (39.0%)	111 (14.9%)	44 (5.9%)	20 (2.7%)	10 (1.3%)	2 (0.%)

5.4 Statistically Significant Relationships between Drivers' Responses

Different responses to questions were compared and analyzed using a Chi-squared test. The Chi-squared test is useful to find out if there is a relationship between drivers' responses to two different questions. The test does not point out what that relationship is; it simply suggests that there is substantial evidence of a relationship by comparing the actual frequency observed to an expected frequency. A greater difference between the actual and expected values suggests a more significant difference in the relationship, something unusual than expected. The BYU Center for Statistical Consultation and Collaborative Research assisted in performing the analysis using SAS statistical analysis software. As seen in the Appendix A, some questions were modified by combining responses or simply eliminating them from the analysis to more fully meet the requirements for the test (i.e., the expected values in each cell be greater than or equal to 5). For example, when comparing speed compliance (question 11) to other questions, the last few possible choices (i.e., half and 25 percent of the time, rarely and never) were combined into one category ("50% or less") to better satisfy the assumptions made for the chi-squared test (Appendix A-1). Since very few people circled those responses, the expected values were not sufficient to meet the chi-squared test assumption. Other questions were modified in similar manners to more accurately depict relationships between questions.

After performing approximately 100 Chi-squared tests comparing different questions, a variety of relationships were found. Due to the large number of test performed, a Sidak or Bonferroni test was implemented to avoid making false conclusions. This test suggested that a p-value less than or equal to 0.0005 would produce a more reliable result than the traditional p-value of 0.05. Using a p-value of 0.0005 or smaller would minimize the chances of obtaining a false positive (i.e., the chances that an insignificant relationship be called significant). Based on this criterion, researchers found relationships between speed compliance and other survey questions, between drivers' opinions and their age, and between drivers' responses and the location where the survey was collected. A few other relationships were found to be substantial as well. The results to these comparisons will be discussed in further detail below. From these comparisons, professionals can focus their efforts on specific groups of people to improve the safety and efficiency of school zones. These comparisons also allow for more profound and in-depth conclusions compared to simply considering rough percentages.

5.4.1 Relationships to Speed Compliance in School Zones

From the Chi-squared analysis, three of the survey questions were found to have significant relationships to speed compliance (question 11). Those relationships to speed compliance included having or not having school-aged children (question 3), age (question 1), and the frequency of driving through a school zone (question 10). Another relationship between the extent of exceeding the speed limit (question 12) and the reason for speeding (question 13) was also found. These comparisons provide some possible reasoning and conclusions for why certain people speed in school zones.

The first relationship encountered was speed compliance vs. having school-aged children. The results of the comparison can be seen in Appendix A.1.1 of this report. From the analysis, an observation was made that those who have children are more likely to "always" obey the speed limit than those who do not have children. Of those who do not have children, more people than expected were observed to have chosen a speed compliance of "most of the time" or "75% of the time". The exact opposite was observed for those who have children. Having children definitely affected the way respondents described their compliance to school zone speed limits.

The way people described their compliance to school zone speed limits was also dependent on people's age. The result to this comparison can also be found in Appendix A.1.2. Those between the ages of 16 and 25 years old tended to be more prone to describing their compliance as "most of the time" or "75% of the time" instead of "always" compared to the older age groups. Still, about 52 percent of this age group (16 to 25 years old) said they "always" obey the school zone speed limit, but compared to the other age groups, this was considerably less. The percentage of those who choose "always" when describing their compliance was observed to increase with age.

A relationship between the frequency of driving through a school zone and the admittance to school zone speed limit compliance was also observed (Appendix A.1.3). For those who rarely drive through a school zone, a discovery was made that the amount who admitted to "always" obeying the speed limit were lower than expected and the other responses (i.e., "most of the time", "75% of the time", or "50% of the time") were somewhat higher than expected. Since the main reason for speeding among all drivers was that they were simply unaware of the school zone suggests that drivers who rarely drive through school zones may have more reason to slow down if the school zones are more visible (i.e., better signs and markings, traffic control devices, etc.). These drivers perhaps require more visible and noticeable school zones since they rarely come across such an area and are not as familiar with them. Drivers who commonly drive through school zones seem to be more compliant than those who do not.

The last relationship to speed compliance encountered was drivers' reason for speeding through school zones (Appendix A.1.4). The extent of exceeding the school zone speed limit varied between the different reasons for speeding. Unfortunately, due to the fact that few people choose reason (d) ("You felt it was inconvenient to slow down, even when children were present.") and exceeding the speed limit by 10 mph or more, a third of the cells had expected values less than 5. Nevertheless, the data still suggests that drivers were more likely to exceed the speed limit by 10 mph or more if they choose reason (d) or reason (c) ("You felt it was unnecessary to slow down due to the absence of children."). Even though only 10 people (1.3%) choose reason (d), 5 of those 10 said they have gone 10 mph or more over the speed limit in school zones; which is a much higher percentage compared to the other reasons for speeding. This may or may not be statistically significant due to the small number of people who responded in this manner. Despite relationship between the extent of speeding and reason for speeding, those who choose either reason (c) or (d) may only be significantly influenced by proper law enforcement. Law enforcement is crucial to maintaining lower speeds in school zones by influencing the behavior of drivers who do not find it necessary to slow down in school zones.

From these comparisons, a few conclusions and recommendations can be made to increase speed compliance in school zones. First, if any effort is made to educate and inform the public of the need and importance for slowing down in school zones, then focus should be placed on younger age groups and on those who do not regularly drive through school zones, since these groups are more prone to speeding in school zones. However, efforts should not be solely devoted to these groups alone. Other factors that can improve and increase speed compliance in school zones include more visible signage, markings and traffic control devices, as well as increased law enforcement. The combination of education, traffic engineering and law enforcement together can effectively improve school zone speed limit compliance.

5.4.2 Responses Varying by Age

Three specific relationships were found between the age of those surveyed and other questions. Responses to the importance of slowing down in school zones (question 7) (see Appendix A.2.1), to the helpfulness of SMDs at informing drivers of their speed (question 15) (see Appendix A.2.2), and to the effectiveness of SMDs at making drivers aware of possible danger ahead (question 16) (see Appendix A.2.3), all varied with the age of the respondents.

For those 16 to 25 years old, more people than expected choose “important” or “somewhat important” compared to “extremely important” with respect to slowing down in school zones. Only 80 percent of the respondents from 16 to 25 years old thought it was “extremely important”. In comparison, about 93 percent of the rest of the age groups felt that it was “extremely important” to slow down in school zones. This comparison suggests more of a need to educate and inform drivers between the ages of 16 and 25 years old.

The helpfulness of SMDs at informing drivers of their speed and the effectiveness of SMDs at making drivers aware of possible danger tended to increase with age. This again suggests that more effort may be needed to slow down younger drivers. These comparisons tend to imply that the effectiveness of SMDs increases with the age of drivers. Despite this difference in age groups, SMDs prove to effectively influence drivers' awareness.

Obviously, age influences drivers' attitudes. Even though there is a distinct difference between age groups, difficulty may be encountered when attempting to pinpoint each group to cause them to slow down. If any emphasis is placed on a particular age group to reduce speeds, that emphasis should be placed on younger drivers.

5.4.3 Answers Varying by Location

There were two particular differences in the way drivers responded to the survey questions based on the location the survey was collected. As mentioned earlier, the survey locations were broken up into four main groups: Logan, Salt Lake City, Provo and Pleasant Grove, and Goshen and Santaquin. The two differences between locations included the knowledge of Utah's uniform speed limit for reduced speed school zones (question 8) (see Appendix A.3.1), and the obedience to the school zone speed limit (question 11) (see Appendix A.3.2).

The Goshen and Santaquin area had the highest percentage of respondents who were aware of the uniform speed limit for reduce speed school zones in Utah (95 percent). Logan was the next highest with 75 percent knowing. The Provo and Salt Lake areas had 70 percent and 62 percent respectively. Perhaps the reason the percentage is so high in the Goshen and Santaquin area is that most of the respondents surveyed were parents picking up their children from school and had just driven through a school zone. Regardless of the location, of those who didn't know the speed limit, most guessed the lower 15 mph. Perhaps drivers should be reminded of the uniform speed limit every time they renew their license.

Speed compliance also seemed to vary by location. Again, the Goshen and Santaquin area seemed to be the most compliant with 82 percent saying they “Always” obey the school zone speed limit. The Salt Lake, Logan and Provo/Pleasant Grove areas had 75, 64 and 57 percent of those surveyed say they are always compliant respectively. Goshen was again probably the most compliant due to the large number of parents surveyed. There was a definite relationship between the location and the knowledge of the uniform school zones speed limit and between location and how people described their compliance to school zone speed limits.

5.4.4 Other Relationships

Two other interesting relationships were found to be significant based on both the Chi-squared test and a Fisher’s exact test. The first was that of the 24 Spanish surveys that were filled out; not one of them was unaware of increased fines for speeding in school zones. Of the English surveys, only 76 percent knew of the increased fines (see Appendix A.4.1). The other relationship found was that women tended to respond more toward “extremely important” as opposed to “important” or “somewhat important” when it comes to slowing down in school zones in comparison to men. Eighty-three percent of the men compared to 93 percent of the women said it was “extremely important” to slow down in school zones. As noted, regardless of gender the majority felt it was very important to slow down in school zones (see Appendix A.4.2).

5.5 Chapter Summary

The results of the public survey concluded that there is need to improve school zones in the State of Utah. Necessary improvements include education, better and more effective traffic control devices, and increased law enforcement. Education should focus on the need for slowing down in school zones, as well as informing the public of increased fines for speeding in school zones. Education should be focused at all groups of people, but should have particular emphasis on younger drivers. Traffic controls such as flashing beacons, crossing guards, SMDs, etc. are all effective at increasing speed compliance in school zones. Increasing the visibility of school zones with the use of more noticeable traffic controls can also improve speed limit compliance. Without the help of law enforcement, sufficient compliance can not be achieved. Although most drivers do not require such enforcement, many drivers do need such incentive to slow down in school zones. The combination of education, traffic engineering and law enforcement is the best way to ensure safe and effective school zones throughout the State of Utah.

Chapter 6 Field Evaluation of Speed Monitoring Displays

An in-depth evaluation of the effects of speed monitoring displays (SMDs) on vehicular speeds was performed in four different school zones in the State of Utah. All four school zones had reasonably high approach speed limits (35 mph) compared to the reduced school zone speed limit (20 mph). UDOT traffic and safety engineers collaborated and decided which four school zones would be assessed in the study. For each location, speed data was collected using Timemark road tubes. The initial intent was to collect data before, one to two weeks after, and then again five to six months after the signs were installed. Unfortunately, due to difficulties with the functionality of the SMD signs, some of the data collection had to be delayed or eliminated. Regardless of these difficulties, sufficient data were collected to perform a valuable comparison. The results of the comparison varied between locations. For the most part, SMDs were effective at improving the compliance level of drivers to the reduced speed school zone speed limit.

6.1 Description of Speed Monitoring Display

The SMDs used in this experiment were purchased by UDOT from 3M. The signs were all pole-mounted and displayed the speed of vehicles as seen in Figure 6-1.

The dimensions of the signs are 36 in. by 48 in., and the dimensions of the variable speed display area are 24 in. by 30 in. The speed of vehicles is displayed with fluorescent yellow-green (same color as school zone signs) sliding disks that slide in and out depending on the number. The signs were programmed to function only during the school zone times. The signs were also programmed so that small LED lights in the numbers would flash to attract drivers' attention if they were speeding more than 5 mph over the school zone speed limit (25 mph or more). Most of the signs purchased came equipped with solar panels. The signs with solar power were used at all the locations in the study except for the Goshen site. Unfortunately, most of the solar powered signs experienced difficulties from time to time due to not having sufficient power to function properly. These difficulties hindered some of the data collection efforts; however, sufficient data were collected to make a comparison. The SMDs were all installed on the shoulder of the road between the crosswalk and the school zone speed limit sign (measuring from the crosswalk, approximately 60 percent of the distance from the crosswalk to the flashers). These SMDs helped increase the visibility of the school zones due to their dynamic nature.

(Source: The Salt Lake Tribune, 10/15/2004)

Figure 6-1: SMD in Action at Salt Lake City School Zone

6.2 Description of Study Sites

In order to more fully understand the characteristic of each school zone, a detailed description is provided below.

6.2.1 SR-89 (400 North) at 400 East in Logan, Utah

The first school zone studied is located at the intersection of 400 North and 400 East in Logan, Utah. The school zone protects children crossing 400 North to get to and from Adams Elementary School which is located one block north of the school zone. 400 North is a four-lane roadway with a two-way left-turn lane median and has a downward slope for westbound vehicles. The road also has sufficient shoulder widths to allow cars to park along both sides of the street. Even though the street is a very busy road, houses still align its shoulders. The approach speed limit to the school zone is 35 mph.

For both the eastbound and westbound traffic, there is a School Advance Warning Assembly, which consists of signs S1-1 and W16-9p according to the MUTCD. These signs can be seen in Figure 6-2 and Figure 6-3. The word "SCHOOL" is painted across both lanes of traffic where these signs are located (Figure 6-2).

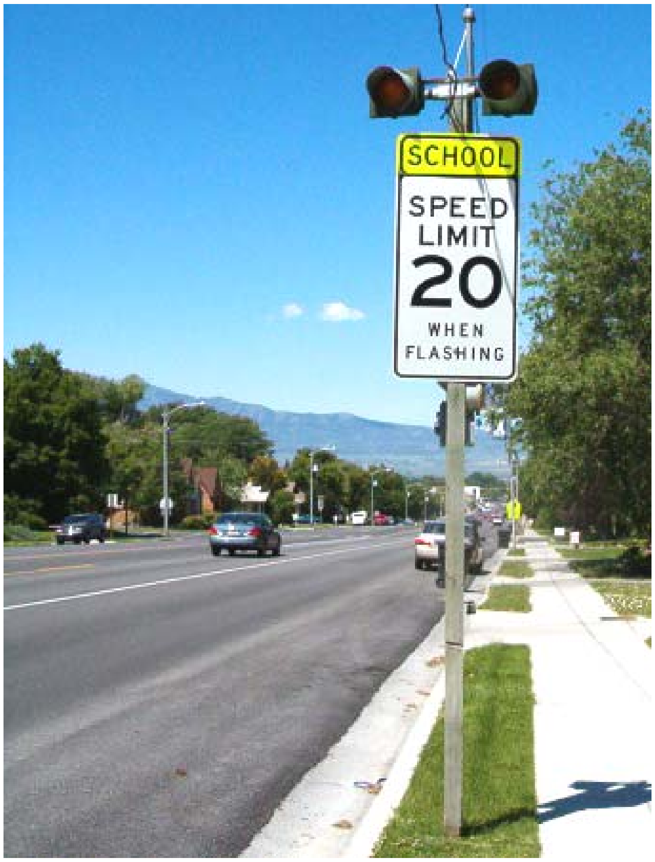
(Photo taken by Kelly Ash 2004)

Figure 6-2: Westbound Approach to the School Zone in Logan

(Photo taken by Kelly Ash 2004)

Figure 6-3: School Advance Warning Assembly for Eastbound SR-89 in Logan

Following the School Advance Warning Assembly on both sides of the street, there is a School Speed Limit Sign with two flashing beacons above it. This sign is S5-1 according to the MUTCD, and can be seen in Figure 6-4. These signs state that the speed limit is 20 mph when flashing and advise drivers that children may be crossing the street. From the School Speed Limit Sign to the intersection, a solid white line to dissuade drivers from making lane changes separates the traffic lanes in each direction.



(Photo taken by Kelly Ash 2004)

Figure 6-4: School Zone Speed Limit Sign for Westbound SR-89 in Logan

The crosswalk for the school zone is located on the east side of the intersection and crosses 400 N. It consists of large white rectangles painted parallel to the flow of traffic. At the crosswalk, for both directions of traffic there is a School Crosswalk Warning Assembly. According to the MUTCD, the School Crosswalk Warning Assembly consists of signs S1-1 and W16-7. The crosswalk and School Crosswalk Warning Assembly can be seen in Figure 6-5. The school zone ends shortly after the crosswalk with an "END SCHOOL ZONE" sign. This is sign S5-2 according to the MUTCD.

(Photo taken by Kelly Ash 2004)

Figure 6-5: School Crosswalk Warning Assembly for Westbound SR-89 in Logan

6.2.2 SR-89 (State Street) at 1110 South in Salt Lake City, Utah

The next school zone studied is located on SR-89, or State Street at about 1110 South in Salt Lake City, Utah. The school zone serves a number of young students that cross State Street to get to and from Lincoln Elementary School. The school is located one block east of the school zone. In this area, State Street receives heavy volumes of traffic and consists of six lanes of traffic with a raised median on a flat grade. The road also has shoulder widths large enough for cars to park along both sides of the street. The street is lined with both houses and small businesses. The approach speed limit to the school zone is 35 mph. For both the northbound and southbound traffic, there is a School Advance Warning Assembly, which consists of signs S1-1 and W16-9p according to the MUTCD. Figure 6-6 shows the School Advance Warning Assembly for the southbound traffic.

(Photo taken by Kelly Ash 2004)

Figure 6-6: School Advance Warning Assembly for Southbound SR-89 in Salt Lake City

Pavement markings are also used to denote the presence of a school zone. The word “SCHOOL” is painted twice across the three lanes of traffic in each direction just upstream from where the School Advance Warning Assemblies are located. Also, from the School Advance Warning Assembly to the stop bar of the intersection, solid white painted lines are used to separate the traffic lanes in order to discourage lane changes. These pavement markings help notify drivers of the school zone.

Following the School Advance Warning Assembly for both directions of traffic, there are two large School Speed Limit Signs (one in the median and one on the shoulder). These signs display the 20 mph school zone speed limit and state that the speed limit is in effect when the lights are flashing. This sign is referred to as S5-1 according to the MUTCD. For both northbound and southbound traffic, one of these signs is placed in the median and has two flashing beacons above it, and the other is on the shoulder of the roadway and has one flashing beacon above the sign, and another below it. These signs can be seen in Figure 6-7.

(Photo taken by Kelly Ash 2004)

Figure 6-7: School Zone Speed Limit Signs for Northbound SR-89 in Salt Lake City

At the crosswalk, for both directions of traffic there is a School Crosswalk Warning Assembly. This sign can be seen in Figure 6-8. According to the MUTCD, these signs are known as S1-1 and W16-7. The crosswalk itself consists of large white rectangles painted parallel to the flow of traffic, and is located on the north side of the intersection. There is a stop bar painted just before the crosswalk for both directions of traffic. The crosswalk can be seen in Figure 6-9. The school zone ends shortly after the crosswalk with an “END SCHOOL ZONE” sign (S5-2 according to the MUTCD).

(Photo taken by Kelly Ash 2004)

Figure 6-8: School Crosswalk Warning Assembly for Northbound SR-89 in Salt Lake City


(Photo taken by Kelly Ash 2004)

Figure 6-9: School Zone Crosswalk Viewed from the West Side of SR-89 in Salt Lake City

6.2.3 SR-146 (100 East) at 1800 North in Pleasant Grove, Utah

The third school zone studied is located along State Route 146 in Pleasant Grove, Utah. This school zone serves a very large number of young students crossing 100 East (SR-146) at 1800 North to get to and from Manila Elementary School. SR-146 is a two-lane highway with a two-way left-turn lane median on the south side of the intersection and no median on the north side of the intersection. The road has a slight downhill grade for southbound traffic. On the south side of the intersection, SR-146 is lined with sidewalks on both sides of the street. However, the north side of the intersection has soft shoulders. Both approaches to the school zone are equipped with a School Advance Warning Assembly (signs S1-1 and W16-9p according to the MUTCD); however, the assembly for the southbound traffic lacks the “AHEAD” sign. These signs can be seen in Figure 6-10 and Figure 6-11. Figure 6-11 also demonstrates how the word “SCHOOL” is painted across the approach lane. These pavement markings are located adjacent to the School Advanced Warning Assembly for both directions of traffic.

(Photo taken by Kelly Ash 2004)

Figure 6-10: Southbound Approach to the School Zone in Pleasant Grove

(Photo taken by Kelly Ash 2004)

Figure 6-11: Northbound Approach to the School Zone in Pleasant Grove

Both approaches are also equipped with a School Speed Limit Sign with two flashing beacons above each. As mentioned earlier, these signs denote that the school zone speed limit is 20 mph when the beacons are flashing. Just like the other school zones studied in this report, the crosswalk consists of large white rectangles painted parallel to the flow of traffic. For both directions of traffic, there is a School Crosswalk Warning Assembly. Figure 6-12 and Figure 6-13 show the School Crosswalk Warning Assemblies for both directions of traffic, as well as the school zone crossing. Shortly following these signs, the school zone ends with an "END SCHOOL ZONE" sign. All of these traffic controls are used to help reduce vehicular speeds during the school zone crossing times.

(Photo taken by Kelly Ash 2004)

Figure 6-12: School Crosswalk Warning Assembly for Southbound SR-146 in Pleasant Grove

(Photo taken by Kelly Ash 2004)

Figure 6-13: School Crosswalk Warning Assembly for Northbound SR-146 in Pleasant Grove

6.2.4 US-6 in Goshen, Utah (Reference Post 153.8)

The last school zone evaluated in this study is located on US-6 at Reference Post (RP) 153.8 in Goshen, Utah. It is adjacent to the Goshen Elementary/Middle School, which is located on the north side of the road. Going through Goshen, SR-6 is a two-lane level highway with a painted two-way left-turn lane median and extremely wide shoulders. A picture of the school zone can be seen in Figure 6-14. Due to the width of the roadway, there is a significant distance that children must travel to cross the street. Along the street, there are a few homes and small businesses surrounding the school. The approach speed limit to the school zone is 35 mph.

(Photo taken by Kelly Ash 2004)

Figure 6-14: Eastbound Approach to the School Zone in Goshen

For both the eastbound and westbound traffic, there is a School Advance Warning Assembly, just like the other school zones. The wide shoulders of the road and the School Advance Warning Assembly for the eastbound traffic are noticed in Figure 6-14. For both directions of traffic, the word “SCHOOL” is painted across the approach lane where the School Advance Warning Assemblies are located.

Following the School Advance Warning Assembly on both sides of the street, there is a School Speed Limit Sign with two flashing beacons above it. Figure 6-15 shows a picture of this sign for the eastbound traffic on US-6 in Goshen. Both the eastbound and westbound signs are both mounted on two wooden poles and say the speed limit is 20 mph when flashing. They also advise the driver that they are entering the school zone and that caution must be taken because children may be crossing.

(Photo taken by Kelly Ash 2004)

Figure 6-15: School Zone Speed Limit Sign for Eastbound Traffic in Goshen

The crosswalk for the school zone is located on the east side of the intersection and consists of large white rectangles painted parallel to the roadway. At the crosswalk, for both directions of traffic there is a School Crosswalk Warning Assembly. The eastbound School Crosswalk Warning Assemblies can be seen in Figure 6-16. The school zone ends shortly after the crosswalk with an "END SCHOOL ZONE" sign (S5-2).

(Photo taken by Kelly Ash 2004)

Figure 6-16: School Crosswalk Warning Assembly for Eastbound US-6 in Goshen

6.3 Spot Speed Study

Speed data were collected in each school zone using Timemark road tube counters. Data were collected just before, about 2 to 4 weeks after and again about 5 to 6 months after the SMDs were installed. Data were collected for approximately 4 days for each collection period. Only speeds during the school zone times were analyzed. The statistics such as the average speed, standard deviation, 85th percentile, percent exceeding the school zone speed limit, and 10 mph pace were all compiled and compared for each school zone. Results of the spot speed study are further discussed below.

6.3.1 Equipment

Two Timemark counters and two sets of tubes were used to collect data for each direction of traffic. Two sets were used to increase the chances that at least one good set of data would be obtained. Each set of tubes consisted of two road tubes laid out approximately 12 feet apart (see Figure 6-17 and Figure 6-18). The two tubes connected to a counter that calculated the speed of each vehicle based on the fraction of time it took for each vehicle to travel from the upstream tube to the downstream tube. The tubes were laid out where the new SMDs were to be located. After the four days of data collect were over, the equipment was taken down and the speed data were downloaded from the counters to be analyzed.

(Photo taken by Kelly Ash 2004)

Figure 6-17: Setting Up Tubes in Goshen

(Photo taken by Kelly Ash 2004)

Figure 6-18: Tube Configuration Shown at the Salt Lake City Site

6.3.2 Procedure

Once the speed data were collected and downloaded from the counters, the researchers needed to determine which speeds were necessary to analyze. Since the flashing beacons were not on timers and only came on when the crossing guards turned them on (not at the exact moment everyday), researchers had to visually determine from the data when the reduced speed school zones had become effective. Another problem in determining which speeds should be analyzed was that some of the speeds were abnormally high and obviously unrealistic. These abnormally high speeds recorded were most likely caused by vehicles in different lanes crossing the tubes at approximately the same time. The counters could not always distinguish between the two vehicles and therefore produced unrealistic results. In order to rid the data of such outliers, researchers decided to eliminate all speeds above 45 mph since that seemed like a realistic cut off for fast speeds observed during visits to the sites. Since the approach speed limit for all the school zones was 35 mph, 10 mph over the approach speed limit seemed like a reasonable and somewhat conservative maximum speed for a cut off. After the data were rid of unnecessary data, the results were compiled for each school zone time period. The outcome of the analysis can be seen in the sections below.

6.4 Speed Results: SR-89 (400 North) at 400 East in Logan, Utah

Before and after speed data were collected at the Logan site. Before data were collected about the middle of September; the SMD signs were installed shortly after that, however, were not functioning properly until about the middle of January. After-data were collected at the end of March. Once the SMDs were actually working as designed, the SMDs proved to be very effective at increase school zone speed limit compliance at this location. Perhaps these SMDs could have been more effective if 3M had provided more technical support to make them work properly. As mentioned earlier, the main problem with the SMDs had something to do with the solar panels and the lack of power they provided. The signs would be able to function properly for a very short period of time; however, due to the lack of power, the signs would suddenly freeze and stop working. Regardless of these difficulties, once the SMDs were functioning properly, they proved to be very effective at increasing speed limit compliance in this school zone.

The results of the analysis can be seen in Table 6-1 and Table 6-2. For both directions of traffic and for both school zone time periods the SMDs were effective at reducing the mean speed, standard deviation, 85th percentile speed, and speed limit compliance. As seen in the table, speeds were initially higher for westbound traffic due to a significant downhill grade. The signs had a drastic impact on drivers traveling westbound. The mean speed decreased by about 3 mph and the 85th percentile speed dropped by about 4 mph. The standard deviation decreased in all cases, suggesting a tighter distribution of speeds (i.e. less outliers). The percent of vehicles exceeding the 20 mph speed limit was greatly reduced and the 10 mph pace decreased by about 3 mph. The percentage of vehicles in the pace increased as well; which suggests an increase in compliance as well. The SMDs also had an impact on the vehicles traveling eastbound; however, due to the uphill grade and already compliant speeds, the changes were not quite as drastic as they were for the westbound traffic. Appendix B-1 shows the distribution of speeds for each time period and direction for this location. As can be seen in the appendix, the distribution of speeds for the westbound traffic suggests that all of the vehicles were influenced by the SMDs; where as of the vehicles traveling eastbound, the faster vehicles were more greatly impacted. The SMDs were extremely effective at increasing and maintaining school zone speed limit compliance at this Logan location.

Table 6-1: Speed Results for Westbound SR-89 (400 North) at 400 East in Logan, Utah

Statistics	Before *(09/13/04 – 09/16/04)*	After *(03/28/05 – 03/31/05)*
Westbound Morning – 7:30 to 8:30 AM		
Mean (mph)	23.24	19.68[a]
Standard Deviation	4.59	3.30
85th Percentile (mph)	26.2	22.1
% Exceeding 20 mph	75.9%	35.7%
10 mph Pace (% in Pace)	17 – 27 (85.9%)	14 – 24 (91.1%)
Sample Size	809	1001
Westbound Afternoon – 2:15 to 3:15 PM		
Mean (mph)	22.99	19.97[a]
Standard Deviation	4.22	3.55
85th Percentile (mph)	26.0	22.5
% Exceeding 20 mph	77.0%	38.7%
10 mph Pace (% in Pace)	17 – 27 (85.9%)	14 – 24 (89.7%)
Sample Size	806	1383

[a] *Difference was statistically significant from the "Before" mean speed based on a Normal Approximation Test at a 95 percent confidence level*

Table 6-2: Speed Results for Eastbound SR-89 (400 North) at 400 East in Logan, Utah

Statistics	Before *(09/13/04 – 09/16/04)*	After *(03/28/05 – 03/31/05)*
Eastbound Morning – 7:30 to 8:30 AM		
Mean (mph)	19.86	18.70[a]
Standard Deviation	4.88	3.50
85th Percentile (mph)	23.3	20.7
% Exceeding 20 mph	32.2%	18.1%
10 mph Pace (% in Pace)	13 – 23 (84.3%)	13 – 23 (91.9%)
Sample Size	699	717
Eastbound Afternoon – 2:15 to 3:15 PM		
Mean (mph)	21.46	19.49[a]
Standard Deviation	5.98	3.51
85th Percentile (mph)	26.0	22.3
% Exceeding 20 mph	45.2%	31.5%
10 mph Pace (% in Pace)	14 – 24 (76.9%)	14 – 24 (90.7%)
Sample Size	863	1131

[a] *Difference was statistically significant from the "Before" mean speed based on a Normal Approximation Test at a 95 percent confidence level*

6.5 Speed Results: SR-89 (State Street) at 1110 South in Salt Lake City, Utah

Before and after speed data were collected at the Salt Lake City location as well. Before-data were collected about the middle of September. Just like the Logan site, the SMDs were not functioning properly until about the middle of January for the same reasons. After-data were collected at the end of March. UDOT placed an extra SMD on the median for northbound traffic in addition to the one on the shoulder to determine if an extra sign would have more influence on drivers' speeds. Unfortunately, the two signs did not function properly together and therefore the sign on the median was turned off. As seen in Table 6-3, speeds were already very compliant to the school zone speed limit at this location despite the functional classification of the roadway. An observation was made by researchers that vehicles arrived at the school zone in platoons; therefore drivers were less likely to speed due to the constraints of other vehicles around them. Since the speed limit compliance during the "Before" condition was already excellent, little difference in speed compliance was observed after the SMDs were installed.

As observed in Table 6-3, the mean speed increased slightly (less than 1 mph) for the northbound traffic, and decreased by about 1 to 2 mph for southbound traffic. The standard deviation remained fairly consistent. The 85th percentile speed decreased by about 1 to 2 mph for the southbound traffic and experience minimal change for the northbound traffic. The percent exceeding the school zone speed limit minimally increased for the northbound traffic, but show a definite decrease for the southbound traffic. The 10 mph pace remained essentially the same for northbound traffic, but did show significant improvements for southbound traffic. As seen in the speed distributions found in Appendix B-2, the SMD signs did not have a very significant effect on vehicles traveling at higher speeds. The signs seemed to affect mostly the vehicles already traveling near or at the school zone speed limit (see southbound results). For the most part, the signs were effective at slowing down vehicles. By no means did the SMDs degrade the safety of the school zone. Had the speed compliance been somewhat worse to begin with, researchers may have observed greater effects caused by the SMDs.

Table 6-3: Speed Results for SR-89 (State Street) at 1110 South in Salt Lake City, Utah

Statistics	Before *(09/13/04 – 09/16/04)*	After *(03/28/05 – 03/31/05)*
Northbound Morning – 7:30 to 8:25 AM		
Mean (mph)	19.06	19.85[a]
Standard Deviation	3.23	3.70
85th Percentile (mph)	21.4	22.4
% Exceeding 20 mph	24.1%	37.0%
10 mph Pace (% in Pace)	14 – 24 (91.9%)	14 – 24 (90.7%)
Sample Size	1223	1069
Northbound Mid-day – 10:55 AM to 12:15 PM		
Mean (mph)	19.85	20.39[a]
Standard Deviation	4.14	4.29
85th Percentile (mph)	22.8	23.3
% Exceeding 20 mph	37.1%	42.0%
10 mph Pace (% in Pace)	14 – 24 (86.9%)	14 – 24 (85.6%)
Sample Size	2056	1796
Northbound Afternoon – 2:30 to 3:15 PM		
Mean (mph)	19.82	20.15
Standard Deviation	4.90	4.77
85th Percentile (mph)	23.2	22.9
% Exceeding 20 mph	35.7%	37.1%
10 mph Pace (% in Pace)	14 – 24 (81.9%)	14 – 24 (84.1%)
Sample Size	926	891
Southbound Morning – 7:30 to 8:25 AM		
Mean (mph)	19.83	18.94[a]
Standard Deviation	4.36	4.23
85th Percentile (mph)	22.7	21.3
% Exceeding 20 mph	40.4%	22.8%
10 mph Pace (% in Pace)	14 – 24 (86.0%)	13 – 23 (87.7%)
Sample Size	463	838
Southbound Mid-day – 10:55 AM to 12:15 PM		
Mean (mph)	20.61	18.84[a]
Standard Deviation	4.32	4.24
85th Percentile (mph)	23.6	21.5
% Exceeding 20 mph	47.1%	22.4%
10 mph Pace (% in Pace)	15 – 25 (85.2%)	13 – 23 (87.7%)
Sample Size	1994	2129
Southbound Afternoon – 2:30 to 3:15 PM		
Mean (mph)	19.95	18.65[a]
Standard Deviation	4.90	4.96
85th Percentile (mph)	23.5	21.8
% Exceeding 20 mph	39.7%	23.0%
10 mph Pace (% in Pace)	14 – 24 (78.6%)	12 – 22 (83.5%)
Sample Size	1409	1091

[a] *Difference was statistically significant from the "Before" mean speed based on a Normal Approximation Test at a 95 percent confidence level*

6.6 Speed Results: SR-146 (100 East) at 1800 North in Pleasant Grove, Utah

Speed data were collected at the Pleasant Grove school zone described above to determine the effectiveness of SMDs at slowing down vehicles. Similar difficulties occurred with the southbound SMD at this location as occurred at the Logan and Salt Lake City locations. For that reason, short-term speed data were only collected for the northbound traffic. Before-data were collected around the beginning of October. The northbound SMD was functioning properly about the first week of November, and the southbound SMD was functioning properly around the beginning of January. For that reason, short-term data were only collected for the northbound direction about the beginning of December. After-data were collected for both directions of traffic about the end of March. The results of the analysis seemed to vary for the two directions of traffic, but may have been caused by the dysfunction of the southbound SMD sign.

As seen in Table 6-4, the results for the northbound morning traffic show that the SMD may have lost effectiveness over time. The short-term results show a significant decrease in the mean speed in the morning for northbound traffic, but the after results show that the mean speed returned to approximately the same speed as the before condition. The mean speed for the northbound vehicles in the afternoon continued to be less than the before condition. Perhaps the lack of long-term effectiveness for the morning time period was the result of more commuters who see the signs everyday. The speed distributions for northbound traffic shown in Appendix B-3 show that the SMD had more influence on higher vehicular speeds in the afternoon than the sign did in the morning. This may also be the result of more commuter traffic on the road in the morning. The southbound SMDs' lack of effectiveness at slowing down vehicles may have been caused by the long time periods where the sign was not functioning. The SMD for the northbound traffic definitely influenced drivers' speeds, and thereby improved the school zone's safety.

Table 6-4: Speed Results for SR-146 (100 East) at 1800 North in Pleasant Grove, Utah

Statistics	Before *(10/04/04 – 10/07/04)*	Short-term *(11/29/04 – 12/02/04)*	After *(03/21/05 – 03/24/05)*
Northbound Morning – 8:15 to 8:50 AM			
Mean (mph)	19.88	18.81[a]	19.80[b]
Standard Deviation	4.44	4.16	3.78
85th Percentile (mph)	24.2	22.4	23.3
% Exceeding 20 mph	40.7%	27.4%	34.0%
10 mph Pace (% in Pace)	14 – 24 (77.4%)	13 – 23 (82.0%)	15 – 25 (86.6%)
Sample Size	513	678	777
Northbound Afternoon – 3:25 to 4:00 PM			
Mean (mph)	20.98	19.38[a]	19.25[a]
Standard Deviation	6.33	5.84	3.70
85th Percentile (mph)	26.7	24.2	22.1
% Exceeding 20 mph	45.9%	34.7%	32.9%
10 mph Pace (% in Pace)	13 – 23 (68.3%)	13 – 23 (71.3%)	13 – 23 (86.8%)
Sample Size	1052	926	856
Southbound Morning – 8:15 to 8:50 AM			
Mean (mph)	21.58	N/A	22.69[a]
Standard Deviation	4.92	N/A	4.09
85th Percentile (mph)	25.7	N/A	26.1
% Exceeding 20 mph	60.6%	N/A	76.0%
10 mph Pace (% in Pace)	16 – 26 (75.2%)	N/A	17 – 27 (83.0%)
Sample Size	926	N/A	317
Southbound Afternoon – 3:25 to 4:00 PM			
Mean (mph)	22.49	N/A	22.04
Standard Deviation	5.37	N/A	4.72
85th Percentile (mph)	27.0	N/A	25.2
% Exceeding 20 mph	67.6%	N/A	67.0%
10 mph Pace (% in Pace)	17 – 27 (71.3%)	N/A	15 – 25 (81.4%)
Sample Size	1061	N/A	194

[a] *Difference was statistically significant from the "Before" mean speed based on a Normal Approximation Test at a 95 percent confidence level*

[b] *Difference was statistically significant from the "Short-term" mean speed based on a Normal Approximation Test at a 95 percent confidence level*

6.7 Speed Results: US-6 in Goshen, Utah (RP 153.8)

Since the SMDs at the Goshen location were hard wired instead of being powered by solar panels, there were no apparent difficulties with the new signs at this location. For that reason, speed data were collected before, about 3 weeks after and again about 5 months after the new SMDs were installed. Unfortunately, both sets of tubes used to collected data for the eastbound direction during the short-term collection period failed to collect sufficient data; therefore, as seen in Table 6-5, this section is omitted for the eastbound analysis. The results obtained from the before and after comparisons of this site can be seen in Table 6-5 and Table 6-6.

The results of the eastbound data collection actually show somewhat of an increase in speeds through the school zone (Table 6-5). The increase is fairly minor (1 to 2 mph). Reasons for the increase are unknown. The mid-day school zone time period (kindergarten crossing) shows essentially no change in speed compliance; however, the rest of the time periods do show a somewhat significant decline in speed compliance compared to the before condition. The speed distributions shown in Appendix B-4 show that during the morning and mid-day time periods, the SMDs had a noticeable influence on excessive speeds through the school zone despite the increase and lack of change in the mean speeds for these time periods. Regardless of the increase in the mean speeds, drivers traveling through this school zone are still very compliant to the reduced speed school zone speed limit. The SMD may have been more effective if the shoulders of the road weren't so wide. Though not drastic, the SMD for the eastbound direction did help improve the safety of the school zone by decreasing excessive speeds during the morning hours.

Table 6-5: Speed Results for Eastbound US-6 in Goshen, Utah (RP 153.8)

Statistics	**Before** *(09/27/04 – 09/30/04)*	**After** *(03/21/05 – 03/24/05)*
Eastbound Morning – 8:10 to 9:00 AM		
Mean (mph)	19.75	21.66[a]
Standard Deviation	4.69	3.18
85th Percentile (mph)	23.4	24.4
% Exceeding 20 mph	38.2%	63.9%
10 mph Pace (% in Pace)	15 – 25 (81.9%)	16 – 26 (88.2%)
Sample Size	144	119
Eastbound Mid-day – 11:15 to 11:45 AM and 12:10 to 12:45 PM		
Mean (mph)	22.17	21.88
Standard Deviation	5.53	3.81
85th Percentile (mph)	27.0	24.9
% Exceeding 20 mph	55.6%	63.1%
10 mph Pace (% in Pace)	15 – 25 (76.3%)	16 – 26 (87.7%)
Sample Size	169	260
Eastbound Afternoon – 2:45 to 3:20 PM		
Mean (mph)	19.72	22.05[a]
Standard Deviation	4.48	5.27
85th Percentile (mph)	23.5	24.9
% Exceeding 20 mph	38.9%	63.8%
10 mph Pace (% in Pace)	14 – 24 (79.0%)	16 – 26 (83.5%)
Sample Size	167	127
Eastbound Late-Afternoon – 3:45 to 5:00 PM		
Mean (mph)	22.02	23.12[a]
Standard Deviation	5.33	5.54
85th Percentile (mph)	27.3	26.4
% Exceeding 20 mph	53.7%	68.2%
10 mph Pace (% in Pace)	15 – 25 (74.6%)	16 – 26 (80.5%)
Sample Size	335	236

[a] *Difference was statistically significant from the "Before" mean speed based on a Normal Approximation Test at a 95 percent confidence level*

The results of the westbound analysis in Goshen were somewhat different than the results of the eastbound analysis (Table 6-6). The morning and afternoon result showed no change in the mean speed. The mean speed for the mid-day analysis decreased and maintained the decrease in speed through the after analysis. The mean speed for the late-afternoon analysis also experienced a decrease in the short-term, but returned to the original speed in the after analysis. This loss in effectiveness of the SMD may have been caused by an increase in commuter traffic during the later afternoon hours. By no means did the SMD decrease the safety of the school zone. The SMD may have been more effective with narrower shoulders.

Table 6-6: Speed Results for Westbound US-6 in Goshen, Utah (RP 153.8)

Statistics	Before *(09/27/04 – 09/30/04)*	Short-term *(11/29/04 – 12/02/04)*	After *(03/21/05 – 03/24/05)*
Westbound Morning – 8:10 to 9:00 AM			
Mean (mph)	22.09	21.86	21.77
Standard Deviation	6.36	5.93	4.56
85^{th} Percentile (mph)	28.3	27.8	27.3
% Exceeding 20 mph	55.2%	47.2%	50.9%
10 mph Pace (% in Pace)	14 – 24 (68.0%)	15 – 25 (70.8%)	16 – 26 (76.9%)
Sample Size	125	161	108
Westbound Mid-day – 11:15 to 11:45 AM and 12:10 to 12:45 PM			
Mean (mph)	23.99	21.56[a]	22.17[a]
Standard Deviation	5.47	4.66	5.29
85^{th} Percentile (mph)	29.4	26.5	27.5
% Exceeding 20 mph	71.9%	52.7%	52.1%
10 mph Pace (% in Pace)	16 – 26 (74.0%)	16 – 26 (76.1%)	15 – 25 (73.6%)
Sample Size	146	222	140
Westbound Afternoon – 2:45 to 3:20 PM			
Mean (mph)	20.96	20.68	20.79
Standard Deviation	4.94	4.81	5.04
85^{th} Percentile (mph)	25.3	24.3	25.8
% Exceeding 20 mph	47.2%	43.8%	40.8%
10 mph Pace (% in Pace)	15 – 25 (76.4%)	14 – 24 (81.3%)	15 – 25 (74.8%)
Sample Size	229	267	103
Westbound Late-Afternoon – 3:45 to 5:00 PM			
Mean (mph)	21.61	20.73[a]	21.49
Standard Deviation	5.09	4.60	4.75
85^{th} Percentile (mph)	25.9	24.8	26.3
% Exceeding 20 mph	53.2%	43.3%	50.0%
10 mph Pace (% in Pace)	16 – 26 (77.3%)	14 – 24 (81.3%)	16 – 26 (79.3%)
Sample Size	295	374	92

[a] *Difference was statistically significant from the "Before" mean speed based on a Normal Approximation Test at a 95 percent confidence level*

[b] *Difference was statistically significant from the "Short-term" mean speed based on a Normal Approximation Test at a 95 percent confidence level*

6.8 Chapter Summary

In summary, the SMDs analyzed in this study proved to increase speed compliance in most cases. In only a few cases and for unknown reasons did the speeds increase after the new signs were installed. In some cases where multiple evaluations were completed (i.e., before, short-term and after), the SMDs maintained their effectiveness at increasing speed compliance; on the other hand, some lost some of their effectiveness possibly due to higher percentages of commuter traffic. As observed in the distribution of speeds at essentially every location, excessive speeds were reduced. In all cases, the safety of the school zone was not degraded by the installation of these signs. For the most part, these SMDs helped improve school zone safety by decreasing speeds and increasing speed compliance as manifested by the decrease in mean speed, standard deviation, 10 mph pace range and the percentage of vehicles exceeding the 20 mph school zone speed limit.

Chapter 7 Conclusions and Recommendations

7.1 Summary

School zones are necessary to guarantee the safety and security of young children crossing the street to and from school; however, each school zone does not provide the same level of efficiency and safety. School zones must warn drivers of the presence of children crossing the street. School zones also can be used to create safe and appropriate gaps in traffic for children to cross as a result of reducing vehicular speeds. The purpose of this study was to determine the most efficient ways to increase and maintain speed compliance in reduced speed school zones. The major tasks of this study are listed below:

- Literature Search
- Public Opinion Survey
- Field Evaluation of SMDs

7.2 Findings

7.2.1 Literature Search

The first goal of this study was to perform an in-depth literature search specifically on how to increase speed compliance in school zones. As part of the literature review, a number of different traffic controls and methods for reducing speeds in school zones were researched to determine their effectiveness. As a result of the extensive literature search, a conclusion was reached that a combination of factors must be present in order for drivers to be more obedient to the school zone speed limit. Those factors include uniformity of traffic controls, effective and noticeable traffic controls, both pedestrian and driver education and awareness, and proper law enforcement.

7.2.2 Public Opinion Survey

Another purpose of this study was to perform a public opinion survey among Utah drivers. The results of the public survey concluded that Utah drivers feel there is need to improve school zones in the State of Utah. Necessary improvements should include education, more effective traffic control devices, and increased law enforcement. Traffic controls such as flashing beacons, crossing guards, SMDs, and fluorescent yellow-green school zone signs all prove to effectively influence drivers to drive slower through school zones. Since the main reason for speeding in school zones among Utah drivers was that they did not noticing the school zone, increasing the visibility of school zones with the use of more noticeable traffic controls can improve speed limit compliance. Without the help of law enforcement, sufficient compliance cannot be achieved.

7.2.3 Field Evaluation of SMDs

The effectiveness of SMDs at increasing speed limit compliance in four school zones in the state was analyzed. The SMDs analyzed in this study proved to increase speed compliance in most cases. In some cases where multiple evaluations were completed (i.e., before, short-term and after), the SMDs maintained their effectiveness at increasing speed compliance; on the other hand, some lost some of their effectiveness possibly due to higher percentages of commuter traffic. As observed in the distribution of speeds at essentially every location, excessive speeds were reduced. In all cases, the safety of each school zone was not degraded by the installation of these SMD signs. For the most part, these SMDs helped improve school zone safety by decreasing speeds and increasing speed compliance as manifested by the decrease in mean speed, standard deviation, 10 mph pace range and the percentage of vehicles exceeding the 20 mph school zone speed limit.

7.3 Recommendations

The combination of education, traffic engineering and law enforcement is the best way to ensure safe and effective school zones throughout the State of Utah. UDOT and other transportation agencies should continually strive to improve school zone safety. School zone safety can be enhanced through better and more noticeable traffic controls, increased public education, and appropriate law enforcement. As mentioned earlier, SMDs can be an effective traffic control in school zones since they undoubtedly help increase speed compliance. SMDs should be used in school zones with excessive speeds and other areas where high speeds may result in unsafe conditions. Since the results of the field study differed by location, further research should be done to determine other factors and conditions that contribute to and influence the effectiveness of SMDs. By effectively reducing speeds in school zones, both the safety and efficiency of those school zones will be substantially improved.

References

"A Guide to School Area Safety." Oregon Department of Transportation, February 2005.

Aggarwal, G. C. and S. L. Mortensen. Do Advance School Flashers Reduce Speed? *ITE Journal*, October 1993, pp. 24-30.

Anderson, R. W. G., A. J. McLean, B. H. L. Farmer, and C. G. Brooks. Vehicle Travel Speeds and the Incidence of Fatal Pedestrian Crashes. *Accident Analysis and Prevention*, 29(5), pp. 667-674, 1997.

Bloch, S. A. Comparative Study of Speed Reduction Effects of Photo-Radar and Speed Display Boards. In *Transportation Research Record 1640*, TRB, National Research Council, Washington D.C., 1998, pp. 27-36.

Burritt, B. E., R. C. Buchanan, and E. I. Kalivoda. School Zone Flashers – Do They Really Slow Traffic? *ITE Journal*, January 1990, pp. 29-31.

Casey, S.M., and A. K. Lund. The Effects of Mobile Roadside Speedometers on Traffic Speeds. *Accident Analysis and Prevention*, 25(5), pp. 627-634, 1993.

City of Garden Grove. Speed Radar Feedback Sign Study. 2003.

Ford Jr., G. L. and D. L. Picha. Teenage Drivers' Understanding of Traffic Control Devices. In *Transportation Research Record 1708*, TRB, National Research Council, Washington D.C., 2000, pp. 1-11.

Hawkins, N. R. Modified Signs, Flashing Beacons and School Zone Speeds. *ITE Journal*, June 1993, pp. 41-44.

Jones, B., A. Griffith, and K. Haas. Effectiveness of Double Fines as a Speed Control Measure in Safety Corridors. Oregon Department of Transportation, Report No. SPR 403-191, December 2002, 35 pp.

Kamyab, A. Methods to Reduce Traffic Speed in High Pedestrian Rural Areas. Paper presented at Transportation Research Board 82nd Annual Meeting, January 2003, Washington D.C., 19 pp.

Lee, K. S. and D. Bullock. Traffic Signals in School Zones. Purdue University, West Lafayette, IN 47907, Report No. FHWA/INDOT/JTRP-2002/32, May 2003, 88 pp.

Manual on Uniform Traffic Control Devices (MUTCD). Federal Highway Administration, U.S. Department of Transportation, 2003 edition.

McCoy, P. T. and J. E. Heimann. School Speed Limits and Speeds in School Zones. In *Transportation Research Record 1254*, TRB, National Research Council, Washington D.C., 1990, pp. 1-7.

McCoy, P. T., A. K. Mohaddes, and R. J. Haden. Effectiveness of School Speed Zones and Their Enforcement. In *Transportation Research Record 811*, TRB, National Research Council, Washington D.C., 1981, pp. 1-7.

Pesti, G. and P. T. McCoy. Long-Term Effectiveness of Speed Monitoring Displays in Work Zones on Rural Interstate Highways. In *Transportation Research Record 1754*, TRB, National Research Council, Washington D.C., 2001, pp. 21-30.

Redmon, T. Assessing the Attitudes and Behaviors of Pedestrians and Drivers in Traffic Situations. *ITE Journal*, April 2003, pp. 26-30.

Reiss, M. L. and H. D. Robertson. Driver Perception of School Traffic Control Devices. In *Transportation Research Record 600*, TRB, National Research Council, Washington D.C., 1976, pp. 36-39.

Rose, E. R. and G. L. Ullman. *Evaluation of Dynamic Speed Display Signs (DSDS)*. Report No. FHWA/TX-04/0-4475-1. Texas Transportation Institute, College Station, TX, September 2003.

Saibel, C., P. Salzberg, R. Doane, and J. Moffat. Vehicle Speeds in School Zones. *ITE Journal*, November 1999, pp. 38-42.

Schrader, M. H. Study of Effectiveness of Selected School Zone Traffic Control Devices. In *Transportation Research Record 1692*, TRB, National Research Council, Washington D.C., 1999, pp. 24-29.

Sparks, J. W. and M. J. Cynecki. Pedestrian Warning Flashers in an Urban Environment: Do They Help? *ITE Journal*, January 1990, pp. 32-36.

Traffic Control for School Zones. Utah Department of Transportation, 2003.

Van Houten, R., D. McCusker, S. Huybers, J. E. L. Malenfant, and D. Rice-Smith. Advance Yield Markings and Fluorescent Yellow-Green RA4 Signs at

Crosswalks with Uncontrolled Approaches. In *Transportation Research Record 1818*, TRB, National Research Council, Washington D.C., 2002, pp. 119-124.

Zegeer, C. V., J. H. Havens, and R. C. Deen,. Speed Reduction in School Zones. In *Transportation Research Record 597*, TRB, National Research Council, Washington D.C., 1976, pp. 39-40.

Appendix A. Public Survey Results

Appendix A.1 Relationships to Speed Compliance

- **Appendix A.1.1 – Speed Compliance vs. Having Kids**
- **Appendix A.1.2 – Speed Compliance vs. Age**
- **Appendix A.1.3 – Speed Compliance vs. Frequency of Driving through a School Zone**
- **Appendix A.1.4 – Extent of Exceeding the Speed Limit vs. Reason for Speeding**

Appendix A.1.1

11.) I obey the speed limit in school zones… *(Circle one)*

Always	Most of the time	About 75% of the time	About half the time	About 25% of the time	Rarely	Never

vs.

Having kids derived from question 3.

Speed Compliance (Question 11)	**Have Kids? (Question 3)**		
Frequency *Expected* *Cell Chi-Square* *Percent* *Row Percent* *Column Percent*	**DO NOT Have Kids**	**Have Kids**	**Total**
Always	281 312.43 3.1615 37.02 57.00 58.42	212 180.57 5.47 27.93 43.00 76.26	493 64.95
Most of Time	146 126.75 2.925 19.24 73.00 30.35	54 73.254 5.0608 7.11 27.00 19.42	200 26.35
~ 75% of Time	32 24.082 2.6036 4.22 84.21 6.65	6 13.918 4.5048 0.79 15.79 2.16	38 5.01
~50% or less	22 17.744 1.0206 2.90 78.57 4.57	6 10.256 1.7659 0.79 21.43 2.16	28 3.69
Total	481 63.37	278 36.63	759 100.00
Frequency Missing = 3			

Statistic	**DF**	**Value**	**Prob**
Chi-Square	3	26.5122	<.0001
Likelihood Ratio Chi-Square	3	27.9346	<.0001
Mantel-Haenszel Chi-Square	1	22.7451	<.0001
Phi Coefficient		0.1869	
Contingency Coefficient		0.1837	
Cramer's V		0.1869	

Appendix A.1.2

11.) I obey the speed limit in school zones… *(Circle one)*

Always	Most of the time	About 75% of the time	About half the time	About 25% of the time	Rarely	Never

vs.

Age derived from question 1.

Speed Compliance (Question 11)	Age (Question 1)				Total
Frequency *Expected* *Cell Chi-Square* *Percent* *Row Percent* *Column Percent*	**16-25**	**26-35**	**35-50**	**Over 50**	**Total**
Always	145 181.96 7.508 19.75 30.40 51.79	139 133.22 0.2506 18.94 29.14 67.80	120 103.98 2.4688 16.35 25.16 75.00	73 57.838 3.9747 9.95 15.30 82.02	477 64.99
Most of Time	99 74.005 8.4416 13.49 51.03 35.36	48 54.183 0.7055 6.54 24.74 23.41	35 42.289 1.2563 4.77 18.04 21.88	12 23.523 5.6448 1.63 6.19 13.48	194 26.43
~ 75% of Time	21 13.351 4.3815 2.86 60.00 7.50	8 9.7752 0.3224 1.09 22.86 3.90	3 7.6294 2.8091 0.41 8.57 1.88	3 4.2439 0.3646 0.41 8.57 3.37	35 4.77
~50% or less	15 10.681 1.7462 2.04 53.57 5.36	10 7.8202 0.6076 1.36 35.71 4.88	2 6.1035 2.7589 0.27 7.14 1.25	1 3.3951 1.6896 0.14 3.57 1.12	28 3.81
Total	280 38.15	205 27.93	160 21.80	89 12.13	734 100.00
Frequency Missing = 28					

Statistic	DF	Value	Prob
Chi-Square	9	44.9303	<.0001
Likelihood Ratio Chi-Square	9	47.2575	<.0001
Mantel-Haenszel Chi-Square	1	34.0987	<.0001
Phi Coefficient		0.2474	
Contingency Coefficient		0.2402	
Cramer's V		0.1428	

Appendix A.1.3

11.) I obey the speed limit in school zones… ***(Circle one)***

Always	Most of the time	About 75% of the time	About half the time	About 25% of the time	Rarely	Never

vs.

10.) How often do you drive through a school zone during the reduced speed times?

a.) More than twice in a day **c.) A few times a week** **e.) Never**
b.) About once or twice a day **d.) Rarely**

Speed Compliance (Question 11)	**Frequency of Driving through a School Zone (Question 10)**				
Frequency Expected Cell Chi-Square Percent Row Percent Column Percent	**More than 2 times a day**	**About 1 or 2 times a day**	**A few times a week**	**Rarely**	**Total**
Always	84 68.521 3.4965 11.62 18.14 78.50	109 102.46 0.4172 15.08 23.54 68.13	184 180.59 0.0644 25.45 39.74 65.25	86 111.43 5.8025 11.89 18.57 49.43	463 64.04
Most of Time	19 29.007 3.4522 2.63 9.69 17.76	41 43.375 0.13 5.67 20.92 25.63	72 76.448 0.2588 9.96 36.73 25.53	64 47.17 6.0047 8.85 32.65 36.78	196 27.11
~ 75% of Time	2 5.4758 2.2063 0.28 5.41 1.87	5 8.1881 1.2413 0.69 13.51 3.13	18 14.432 0.8824 2.49 48.65 6.38	12 8.9046 1.076 1.66 32.43 6.90	37 5.12
~50% or less	2 3.9959 0.9969 0.28 7.41 1.87	5 5.9751 0.1591 0.69 18.52 3.13	8 10.531 0.6083 1.11 29.63 2.84	12 6.4979 4.6588 1.66 44.44 6.90	27 3.73
Total	107 14.80	160 22.13	282 39.00	174 24.07	723 100.00
Frequency Missing = 39					

Statistic	**DF**	**Value**	**Prob**
Chi-Square	9	31.4556	0.0002
Likelihood Ratio Chi-Square	9	31.6902	0.0002
Mantel-Haenszel Chi-Square	1	23.1206	<.0001
Phi Coefficient		0.2086	
Contingency Coefficient		0.2042	
Cramer's V		0.1204	

Appendix A.1.4

12.) When you speed in school zones, approximately how much over the speed limit are you traveling?

a.) 0-5 mph b.) 5-10 mph c.) 10-15 mph d.) 15-20 mph e.) Over 20 mph

vs.

13.) If you have sped through a school zone before, what was the main reason for speeding?

a.) You were not aware it was a school zone until it was too late.
b.) You were in a hurry or late for something (for example, work or school).
c.) You felt it was unnecessary to slow down due to the absence of children.
d.) You felt it was inconvenient to slow down, even when children were present.
e.) Other

Speed (Question 12)	**Reason for Speeding (Question 13)**				
Frequency *Expected* *Cell Chi-Square* *Percent* *Row Percent* *Column Percent*	**Reason (a)**	**Reason (b)**	**Reason (c)**	**Reason (d)**	**Total**
0-5 mph (a)	387 358.5 2.2657 65.37 80.96 87.16	46 53.291 0.9974 7.77 9.62 69.70	41 58.135 5.0505 6.93 8.58 56.94	4 8.0743 2.0559 0.68 0.84 40.00	478 80.74
5-10 mph (b)	38 56.25 5.9211 6.42 50.67 8.56	15 8.3615 5.2706 2.53 20.00 22.73	21 9.1216 15.468 3.55 28.00 29.17	1 1.2669 0.0562 0.17 1.33 10.00	75 12.67
Over 10 mph (c, d, or e)	19 29.25 3.5919 3.21 48.72 4.28	5 4.348 0.0978 0.84 12.82 7.58	10 4.7432 5.8259 1.69 25.64 13.89	5 0.6588 28.608 0.84 12.82 50.00	39 6.59
Total	444 75.00	66 11.15	72 12.16	10 1.69	592 100.00
Frequency Missing = 170					

Statistic	**DF**	**Value**	**Prob**
Chi-Square	6	75.2088	<.0001
Likelihood Ratio Chi-Square	6	53.8808	<.0001
Mantel-Haenszel Chi-Square	1	54.1309	<.0001
Phi Coefficient		0.3564	
Contingency Coefficient		0.3357	
Cramer's V		0.2520	

WARNING: 33% of the cells have expected counts less than 5. Chi-Squared may not be a valid test.

WARNING: 22% of the data are missing since "other" reasons were left out of the analysis.

Appendix A.2 Relationships to Age

- **Appendix A.2.1 – Age vs. Importance of Vehicles Slowing Down in School Zones**
- **Appendix A.2.2 – Age vs. Helpfulness of SMDs at Informing Drivers of Their Speed**
- **Appendix A.2.3 – Age vs. Effectiveness of SMDs at Making Drivers Aware of Possible Danger Ahead**

Appendix A.2.1

Age derived from question 1.
Vs.
7.) In your opinion, how important is it that vehicles slow down in school zones?

Extremely Important   **Important**   **Somewhat Important**   **Not Important**   **No Opinion**

Age (Question 1)	Importance of Vehicles Slowing Down in School Zones (Question 7)		
Frequency Expected Cell Chi-Square Percent Row Percent Column Percent	**Extremely Important**	**Important or Somewhat Important**	**Total**
16-25	221 244.49 2.2564 30.27 79.50 34.42	57 33.512 16.462 7.81 20.50 64.77	278 38.08
26-35	191 181.17 0.5337 26.16 92.72 29.75	15 24.833 3.8934 2.05 7.28 17.05	206 28.22
35-50	147 138.95 0.466 20.14 93.04 22.90	11 19.047 3.3994 1.51 6.96 12.50	158 21.64
Over 50	83 77.392 0.4064 11.37 94.32 12.93	5 10.608 2.9649 0.68 5.68 5.68	88 12.05
Total	642 87.95	88 12.05	730 100.00
Frequency Missing = 32			

Statistic	DF	Value	Prob
Chi-Square	3	30.3820	<.0001
Likelihood Ratio Chi-Square	3	29.5372	<.0001
Mantel-Haenszel Chi-Square	1	21.9668	<.0001
Phi Coefficient		0.2040	
Contingency Coefficient		0.1999	
Cramer's V		0.2040	

Appendix A.2.2

Age derived from question 1.
vs.
15.) How helpful are the electronic signs that display vehicle speeds at informing you of your speed while driving?

a.) Very helpful **c.) Sometimes helpful** **e.) Never helpful; I always know how fast I am going**
b.) Helpful **d.) Rarely helpful**

Age (Question 1)	Helpfulness of SMDs (Question 15)					Total
Frequency *Expected* *Cell Chi-Square* *Percent* *Row Percent* *Column Percent*	**Very helpful**	**Helpful**	**Sometimes Helpful**	**Rarely Helpful**	**Never Helpful**	
16-25	94 125.8 8.0388 13.00 33.69 28.83	73 64.444 1.136 10.10 26.16 43.71	61 49.008 2.9342 8.44 21.86 48.03	34 23.154 5.0811 4.70 12.19 56.67	17 16.593 0.01 2.35 6.09 39.53	279 38.59
26-35	82 89.278 0.5933 11.34 41.41 25.15	39 45.734 0.9917 5.39 19.70 23.35	41 34.78 1.1123 5.67 20.71 32.28	17 16.432 0.0197 2.35 8.59 28.33	19 11.776 4.4317 2.63 9.60 44.19	198 27.39
35-50	96 70.791 8.9769 13.28 61.15 29.45	35 36.264 0.0441 4.84 22.29 20.96	17 27.578 4.0575 2.35 10.83 13.39	6 13.029 3.7921 0.83 3.82 10.00	3 9.3375 4.3013 0.41 1.91 6.98	157 21.72
Over 50	54 40.13 4.7938 7.47 60.67 16.56	20 20.557 0.0151 2.77 22.47 11.98	8 15.633 3.7273 1.11 8.99 6.30	3 7.3859 2.6044 0.41 3.37 5.00	4 5.2932 0.316 0.55 4.49 9.30	89 12.31
Total	326 45.09	167 23.10	127 17.57	60 8.30	43 5.95	723 100.00
Frequency Missing = 39						

Statistic	DF	Value	Prob
Chi-Square	12	56.9772	<.0001
Likelihood Ratio Chi-Square	12	59.5557	<.0001
Mantel-Haenszel Chi-Square	1	35.3903	<.0001
Phi Coefficient		0.2807	
Contingency Coefficient		0.2703	
Cramer's V		0.1621	

Appendix A.2.3

Age derived from question 1.
vs.
16.) The electronic signs that display vehicle speeds are effective at making me aware that there might be danger ahead.

Strongly Agree | **Agree** | **Somewhat Agree** | **No Opinion** | **Somewhat Disagree** | **Disagree** | **Strongly Disagree**

Age (Question 1)	Effectiveness of SMDs at making drivers aware of danger ahead (Question 16)							
Frequency Expected Cell Chi-Square Percent Row Percent Column Percent	Strongly Agree	Agree	Somewhat Agree	No Opinion	Somewhat Disagree	Disagree	Strongly Disagree	Total
16-25	45 65.95 6.6553 6.20 16.07 26.32	101 89.091 1.5919 13.91 36.07 43.72	49 49.366 0.0027 6.75 17.50 38.28	31 25.069 1.4033 4.27 11.07 47.69	29 21.983 2.2395 3.99 10.36 50.88	15 19.669 1.1085 2.07 5.36 29.41	10 8.8705 0.1438 1.38 3.57 43.48	280 38.57
26-35	47 47.107 0.0002 6.47 23.50 27.49	45 63.636 5.4578 6.20 22.50 19.48	47 35.262 3.9076 6.47 23.50 36.72	17 17.906 0.0459 2.34 8.50 26.15	15 15.702 0.0314 2.07 7.50 26.32	20 14.05 2.5202 2.75 10.00 39.22	9 6.3361 1.12 1.24 4.50 39.13	200 27.55
35-50	45 36.979 1.7396 6.20 28.66 26.32	54 49.955 0.3276 7.44 34.39 23.38	25 27.68 0.2596 3.44 15.92 19.53	10 14.056 1.1706 1.38 6.37 15.38	10 12.326 0.4391 1.38 6.37 17.54	12 11.029 0.0855 1.65 7.64 23.53	1 4.9738 3.1749 0.14 0.64 4.35	157 21.63
Over 50	34 20.963 8.1081 4.68 38.20 19.88	31 28.318 0.254 4.27 34.83 13.42	7 15.691 4.8142 0.96 7.87 5.47	7 7.9683 0.1177 0.96 7.87 10.77	3 6.9876 2.2756 0.41 3.37 5.26	4 6.2521 0.8112 0.55 4.49 7.84	3 2.8196 0.0115 0.41 3.37 13.04	89 12.26
Total	171 23.55	231 31.82	128 17.63	65 8.95	57 7.85	51 7.02	23 3.17	726 100.00
Frequency Missing = 36								

Statistic	DF	Value	Prob
Chi-Square	18	49.8173	<.0001
Likelihood Ratio Chi-Square	18	52.5394	<.0001
Mantel-Haenszel Chi-Square	1	13.2066	0.0003
Phi Coefficient		0.2620	
Contingency Coefficient		0.2534	
Cramer's V		0.1512	

Appendix A.3 Relationships to Location

- **Appendix A.3.1 – Location vs. Knowledge of Uniform Reduced School Zone Speed Limit**
- **Appendix A.3.2 – Location vs. Speed Compliance**

Appendix A.3.1

Location survey was collected
vs.
8.) What is the uniform speed limit for reduced speed school zones in Utah?
a.) 15 mph b.) 20 mph c.) 25 mph d.) 30 mph

Location	Knowledge of uniform reduced speed school zone speed limit (Question 8)			Total
Frequency Expected Cell Chi-Square Percent Row Percent Column Percent	**15 mph**	**20 mph**	**25 mph**	
Goshen/ Santaquin	1 12.532 10.611 0.13 1.69 0.62	56 41.798 4.8254 7.39 94.92 10.43	2 4.6702 1.5267 0.26 3.39 3.33	59 7.78
Logan	34 37.595 0.3438 4.49 19.21 21.12	132 125.39 0.348 17.41 74.58 24.58	11 14.011 0.6469 1.45 6.21 18.33	177 23.35
Provo/ Pleasant Grove	72 70.305 0.0409 9.50 21.75 44.72	231 234.49 0.0521 30.47 69.79 43.02	28 26.201 0.1236 3.69 8.46 46.67	331 43.67
Salt Lake	54 40.569 4.4468 7.12 28.27 33.54	118 135.31 2.2151 15.57 61.78 21.97	19 15.119 0.9964 2.51 9.95 31.67	191 25.20
Total	161 21.24	537 70.84	60 7.92	758 100.00
Frequency Missing = 4				

Statistic	DF	Value	Prob
Chi-Square	6	26.1770	0.0002
Likelihood Ratio Chi-Square	6	33.1821	<.0001
Mantel-Haenszel Chi-Square	1	4.7998	0.0285
Phi Coefficient		0.1858	
Contingency Coefficient		0.1827	
Cramer's V		0.1314	

Appendix A.3.2

Location survey was collected
vs.
11.) I obey the speed limit in school zones… *(Circle one)*

Always	Most of the time	About 75% of the time	About half the time	About 25% of the time	Rarely	Never

Speed Compliance (Question 11)	Location				
Frequency Expected Cell Chi-Square Percent Row Pct Col Pct	**Goshen/ Santaquin**	**Logan**	**Provo/ Pleasant Grove**	**Salt Lake**	**Total**
Always	49 38.972 2.5801 6.46 9.94 81.67	115 116.27 0.0138 15.15 23.33 64.25	187 215 3.6459 24.64 37.93 56.50	142 122.76 3.0145 18.71 28.80 75.13	493 64.95
Most of Time	9 15.81 2.9335 1.19 4.50 15.00	51 47.167 0.3114 6.72 25.50 28.49	107 87.22 4.4858 14.10 53.50 32.33	33 49.802 5.6688 4.35 16.50 17.46	200 26.35
~ 75% of Time	0 3.004 3.004 0.00 0.00 0.00	7 8.9618 0.4294 0.92 18.42 3.91	24 16.572 3.3296 3.16 63.16 7.25	7 9.4625 0.6408 0.92 18.42 3.70	38 5.01
~50% or less	2 2.2134 0.0206 0.26 7.14 3.33	6 6.6034 0.0551 0.79 21.43 3.35	13 12.211 0.051 1.71 46.43 3.93	7 6.9723 0.0001 0.92 25.00 3.70	28 3.69
Total	60 7.91	179 23.58	331 43.61	189 24.90	759 100.00
Frequency Missing = 3					

Statistic	DF	Value	Prob
Chi-Square	9	30.1845	0.0004
Likelihood Ratio Chi-Square	9	33.7121	0.0001
Mantel-Haenszel Chi-Square	1	0.1521	0.6966
Phi Coefficient		0.1994	
Contingency Coefficient		0.1956	
Cramer's V		0.1151	

Appendix A.4 Other Relationships

- **Appendix A.4.1 – Language vs. Knowledge of Fines**
- **Appendix A.4.2 – Gender vs. Importance of Vehicles Slowing Down in School Zones**

Appendix A.4.1

Language (English or Spanish)
vs.
19.) Were you aware that there are increased fines for speeding in school zones?
Yes **No**

Language	Knowledge of increased fines (Question 19)		
Frequency *Expected* *Cell Chi-Square* *Percent* *Row Percent* *Column Percent*	**No, did not know**	**Yes, knew**	**Total**
English	166 160.53 0.186 22.77 23.55 100.00	539 544.47 0.0549 73.94 76.45 95.74	705 96.71
Spanish	0 5.465 5.465 0.00 0.00 0.00	24 18.535 1.6114 3.29 100.00 4.26	24 3.29
Total	166 22.77	563 77.23	729 100.00
Frequency Missing = 33			

Statistic	DF	Value	Prob
Chi-Square	1	7.3173	0.0068
Likelihood Ratio Chi-Square	1	12.6419	0.0004
Continuity Adj. Chi-Square	1	6.0396	0.0140
Mantel-Haenszel Chi-Square	1	7.3072	0.0069
Phi Coefficient		0.1002	
Contingency Coefficient		0.0997	
Cramer's V		0.1002	

Fisher's Exact Test	
Cell (1,1) Frequency (F)	166
Left-sided Pr <= F	1.0000
Right-sided Pr >= F	0.0018
Table Probability (P)	0.0018
Two-sided Pr <= P	0.0025

Appendix A.4.2

Gender derived from question 1
vs.
7.) In your opinion, how important is it that vehicles slow down in school zones?
Extremely Important   Important   Somewhat Important   Not Important   No Opinion

Gender	Importance of Vehicles Slowing Down in School Zones (Question 7)		
Frequency Expected Cell Chi-Square Percent Row Percent Column Percent	**Extremely Important**	**Important or Somewhat Important**	**Total**
Female	329 314.32 0.6856 47.61 91.64 54.38	30 44.68 4.8233 4.34 8.36 34.88	359 51.95
Male	276 290.68 0.7414 39.94 83.13 45.62	56 41.32 5.2156 8.10 16.87 65.12	332 48.05
Total	605 87.55	86 12.45	691 100.00
Frequency Missing = 71			

Statistic	DF	Value	Prob
Chi-Square	1	11.4660	0.0007
Likelihood Ratio Chi-Square	1	11.5785	0.0007
Continuity Adj. Chi-Square	1	10.6982	0.0011
Mantel-Haenszel Chi-Square	1	11.4494	0.0007
Phi Coefficient		0.1288	
Contingency Coefficient		0.1278	
Cramer's V		0.1288	

Fisher's Exact Test	
Cell (1,1) Frequency (F)	329
Left-sided Pr <= F	0.9998
Right-sided Pr >= F	5.119E-04
Table Probability (P)	2.951E-04
Two-sided Pr <= P	7.821E-04

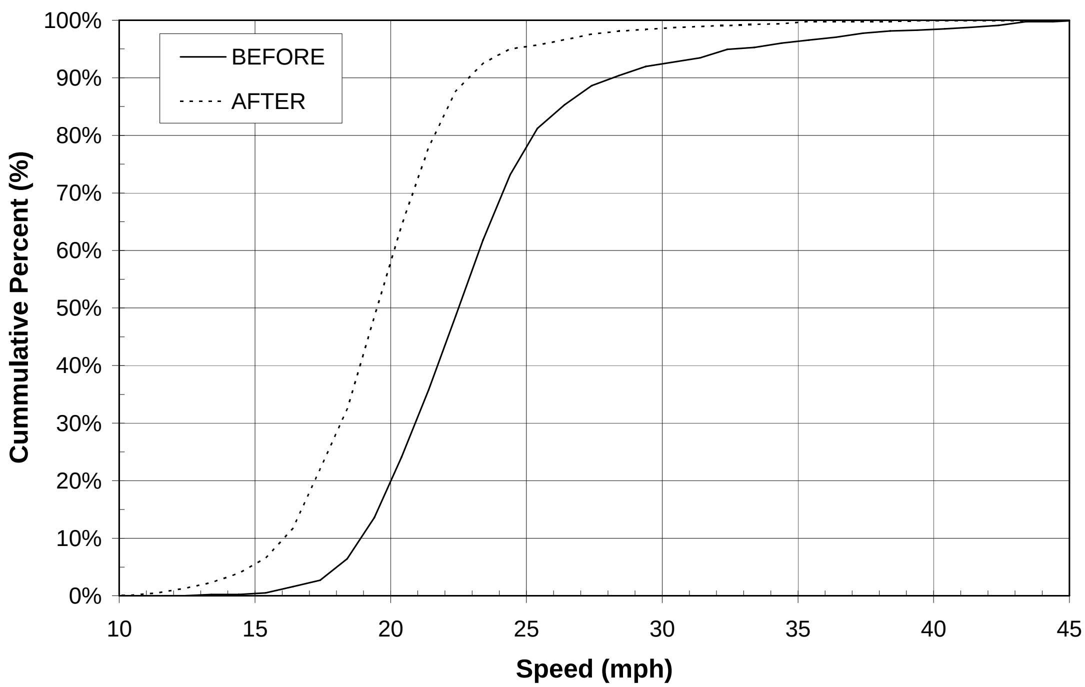
Appendix B. Spot Speed Study Results

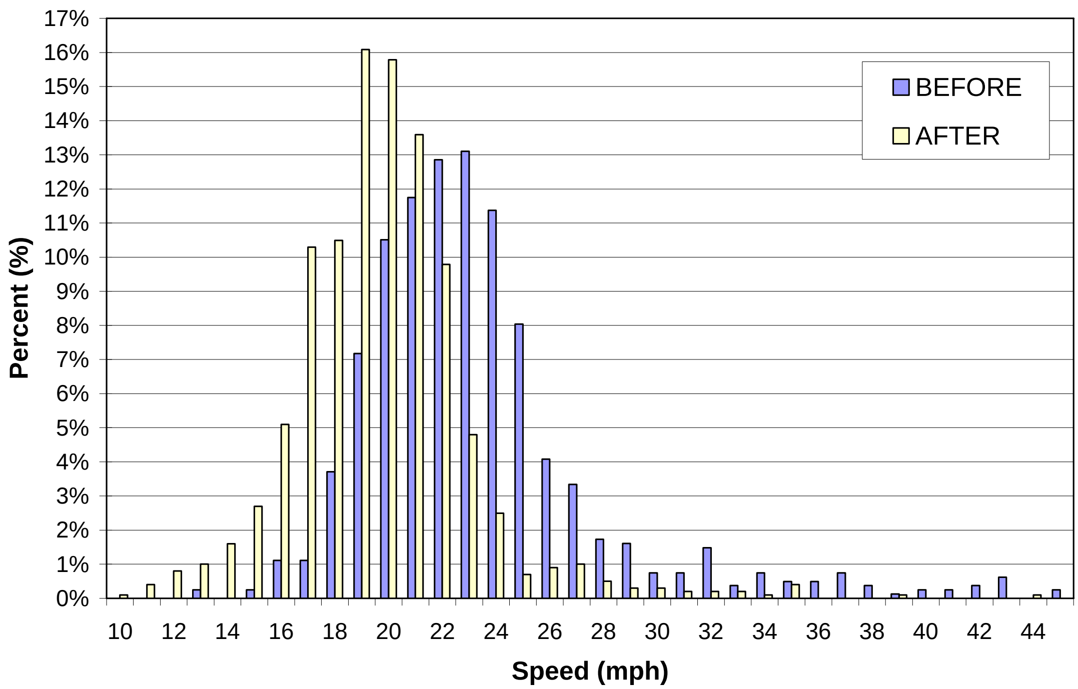
Appendix B-1.   Logan Results

Logan Westbound Morning

7:30 AM to 8:30 AM

	Before *(09/13/04 – 09/16/04)*	**After** *(03/28/05 – 03/31/05)*
Mean (mph)	23.24	19.68
Standard Deviation	4.59	3.30
85th Percentile (mph)	26.2	22.1
% Exceeding 20 mph	75.9%	35.7%
10 mph Pace (% in Pace)	17 – 27 (85.9%)	14 – 24 (91.1%)
Sample Size	809	1001

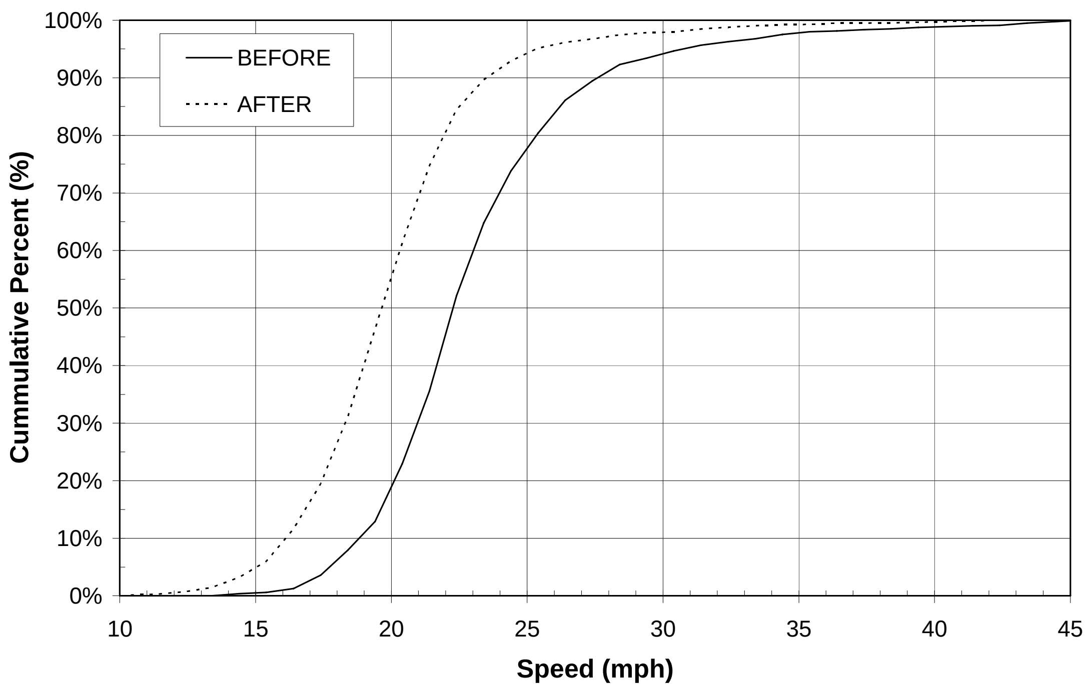


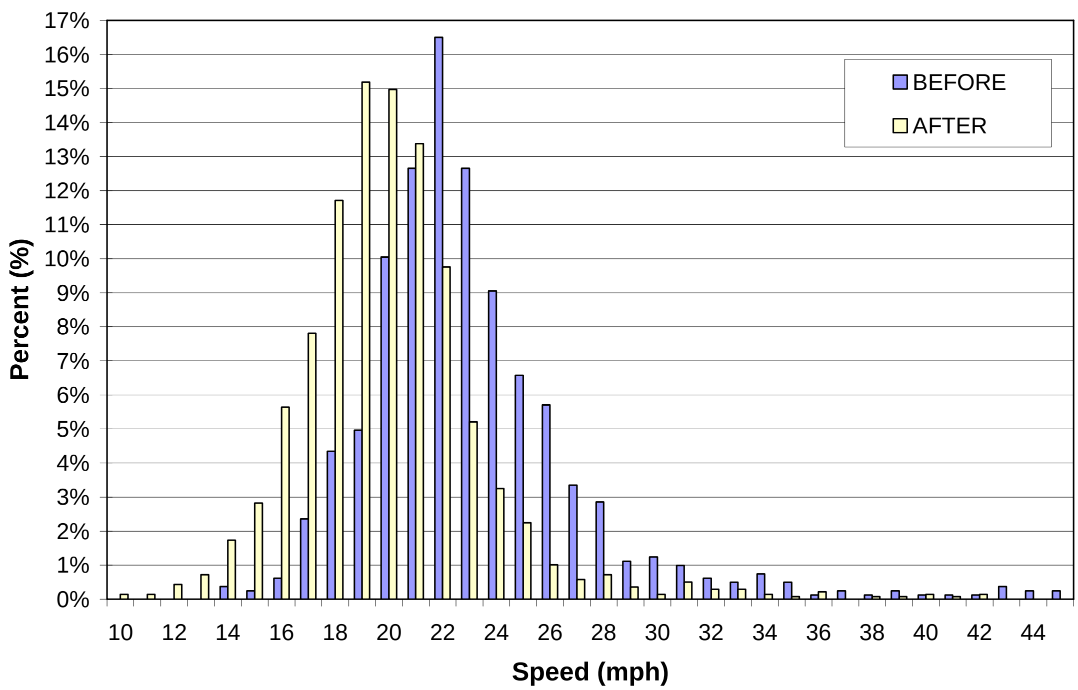


Logan Westbound Afternoon

2:15 PM to 3:15 PM

	Before (09/13/04 – 09/16/04)	After (03/28/05 – 03/31/05)
Mean (mph)	22.99	19.97
Standard Deviation	4.22	3.55
85th Percentile (mph)	26.0	22.5
% Exceeding 20 mph	77.0%	38.7%
10 mph Pace (% in Pace)	17 – 27 (85.9%)	14 – 24 (89.7%)
Sample Size	806	1383

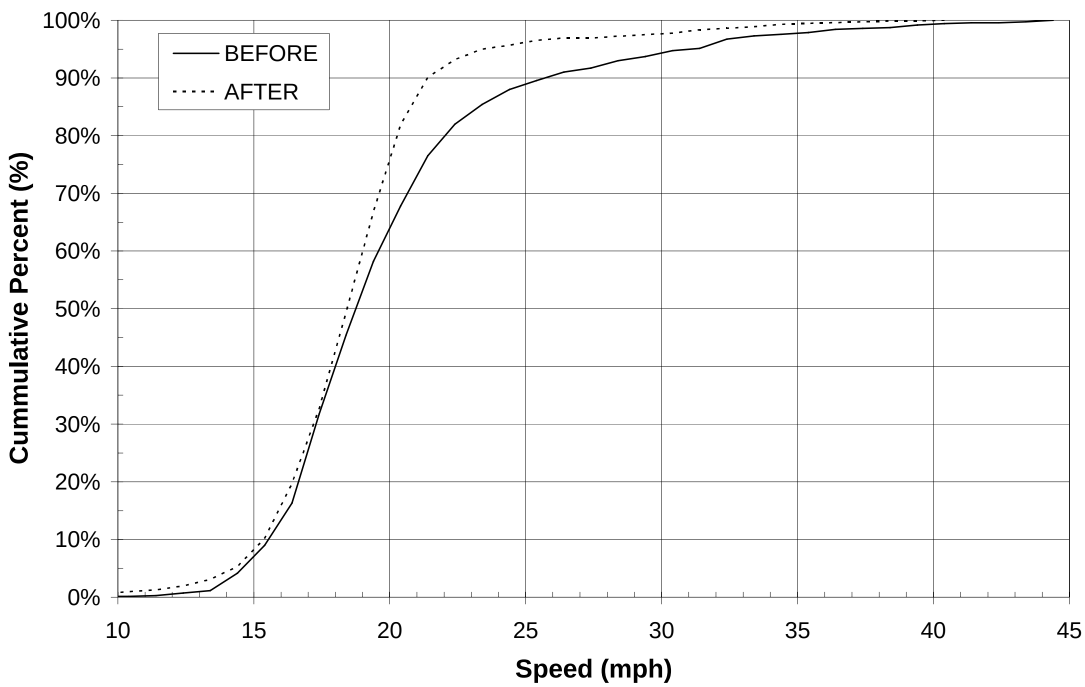


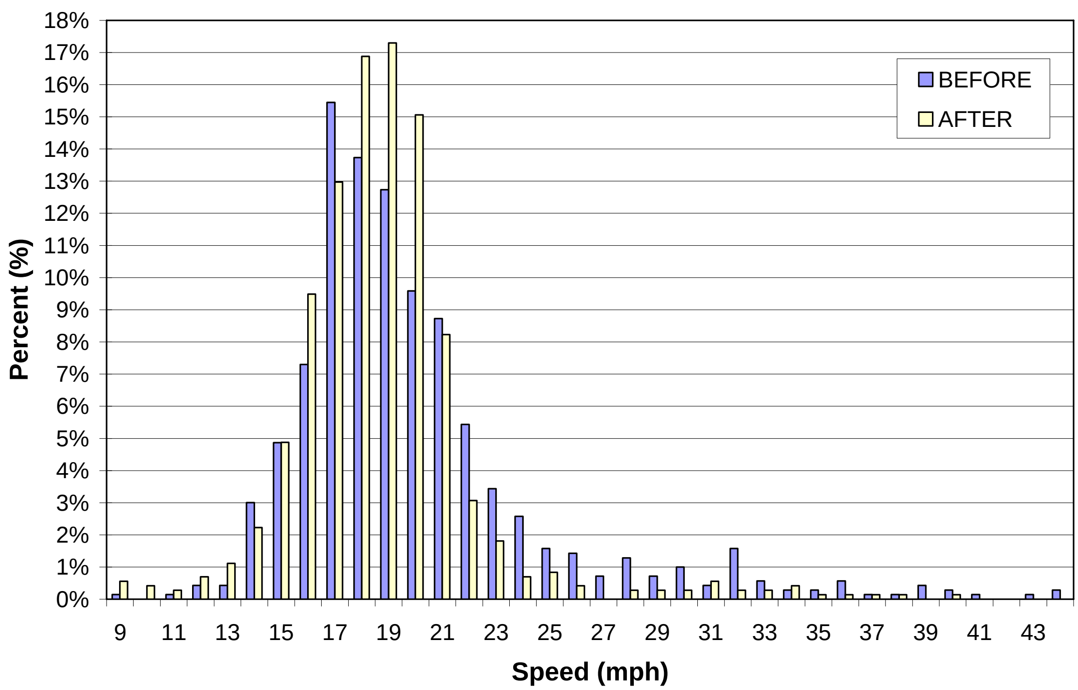


Logan Eastbound Morning

7:30 AM to 8:30 AM

	Before *(09/13/04 – 09/16/04)*	After *(03/28/05 – 03/31/05)*
Mean (mph)	19.86	18.70
Standard Deviation	4.88	3.50
85th Percentile (mph)	23.3	20.7
% Exceeding 20 mph	32.2%	18.1%
10 mph Pace (% in Pace)	13 – 23 (84.3%)	13 – 23 (91.9%)
Sample Size	699	717

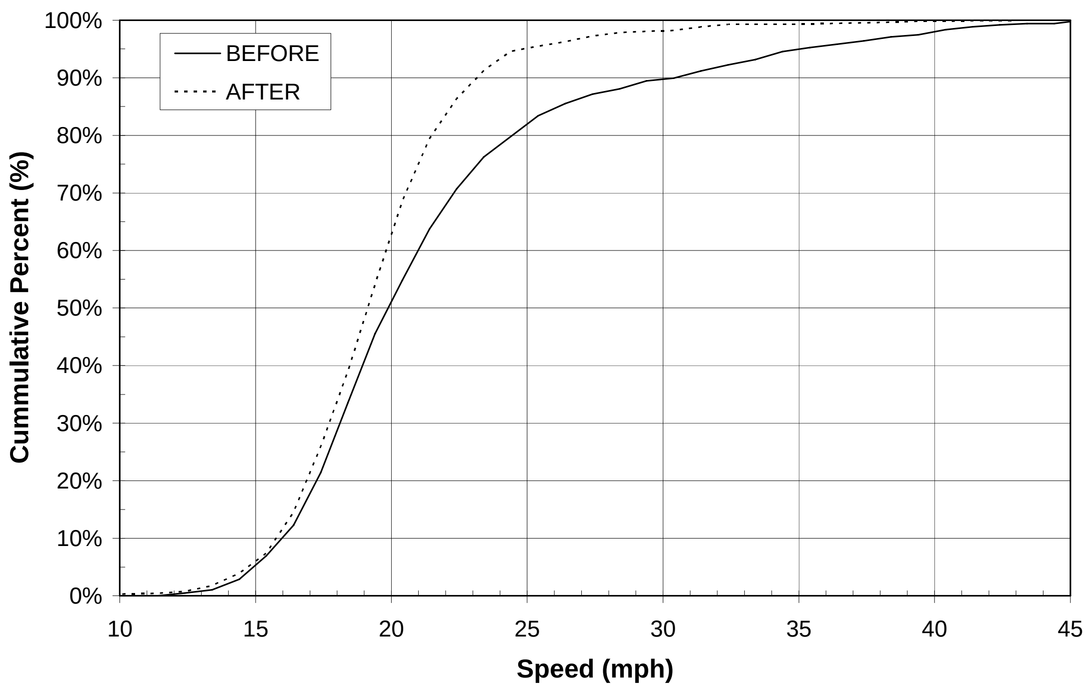


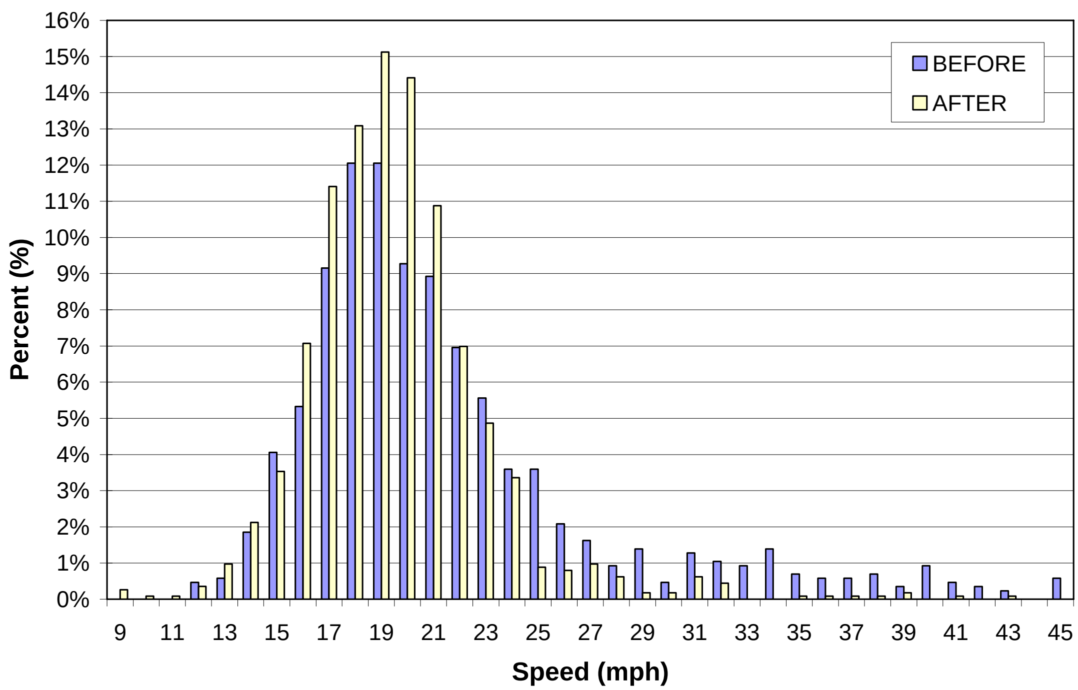


Logan Eastbound Afternoon

2:15 PM to 3:15 PM

	Before *(09/13/04 – 09/16/04)*	After *(03/28/05 – 03/31/05)*
Mean (mph)	21.46	19.49
Standard Deviation	5.98	3.51
85^{th} Percentile (mph)	26.0	22.3
% Exceeding 20 mph	45.2%	31.5%
10 mph Pace (% in Pace)	14 – 24 (76.9%)	14 – 24 (90.7%)
Sample Size	863	1131



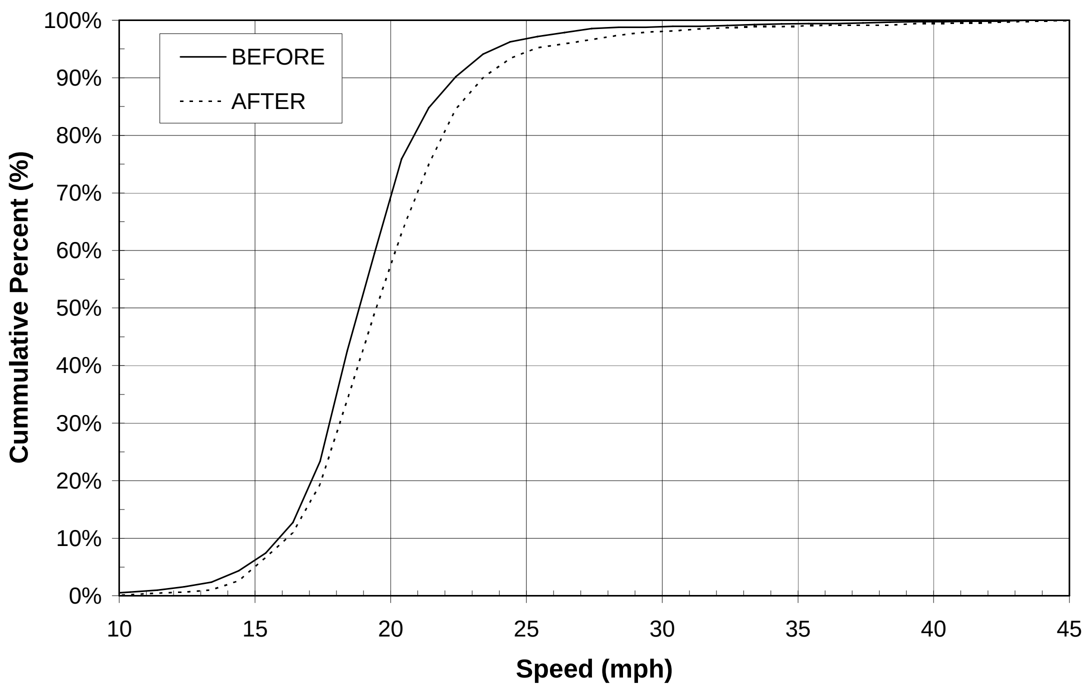


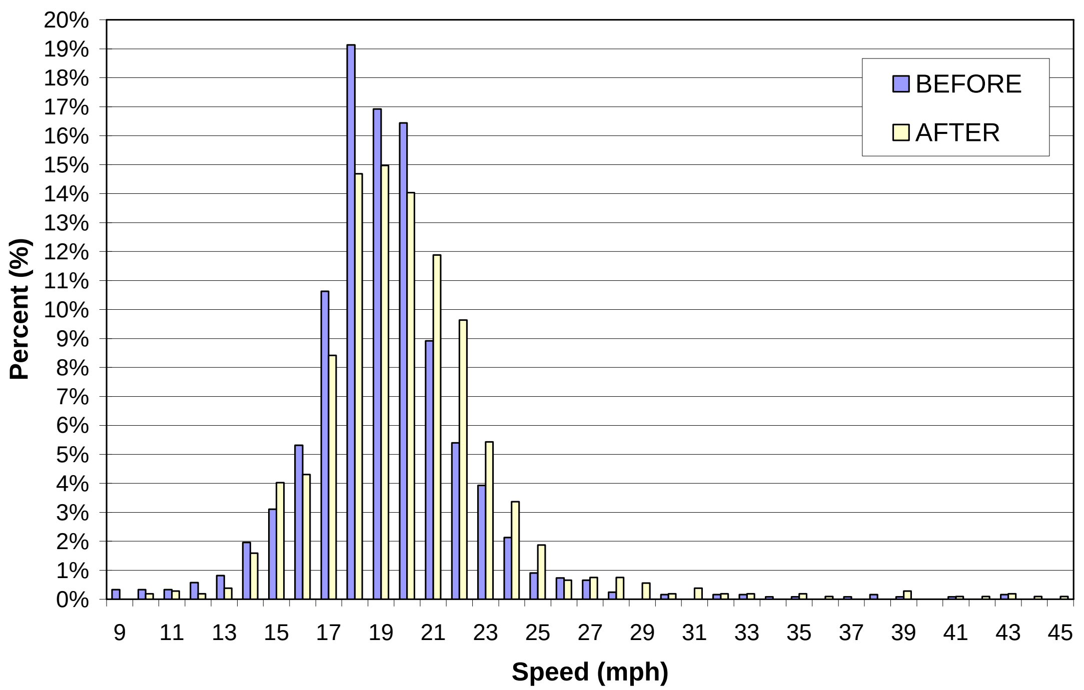
Appendix B-2. Salt Lake City Results

Salt Lake City Northbound Morning

7:30 AM to 8:25 AM

	Before *(09/20/04 – 09/23/04)*	After *(04/04/05 – 04/07/05)*
Mean (mph)	19.06	19.85
Standard Deviation	3.23	3.70
85th Percentile (mph)	21.4	22.4
% Exceeding 20 mph	24.1%	37.0%
10 mph Pace (% in Pace)	14 – 24 (91.9%)	14 – 24 (90.7%)
Sample Size	1223	1069

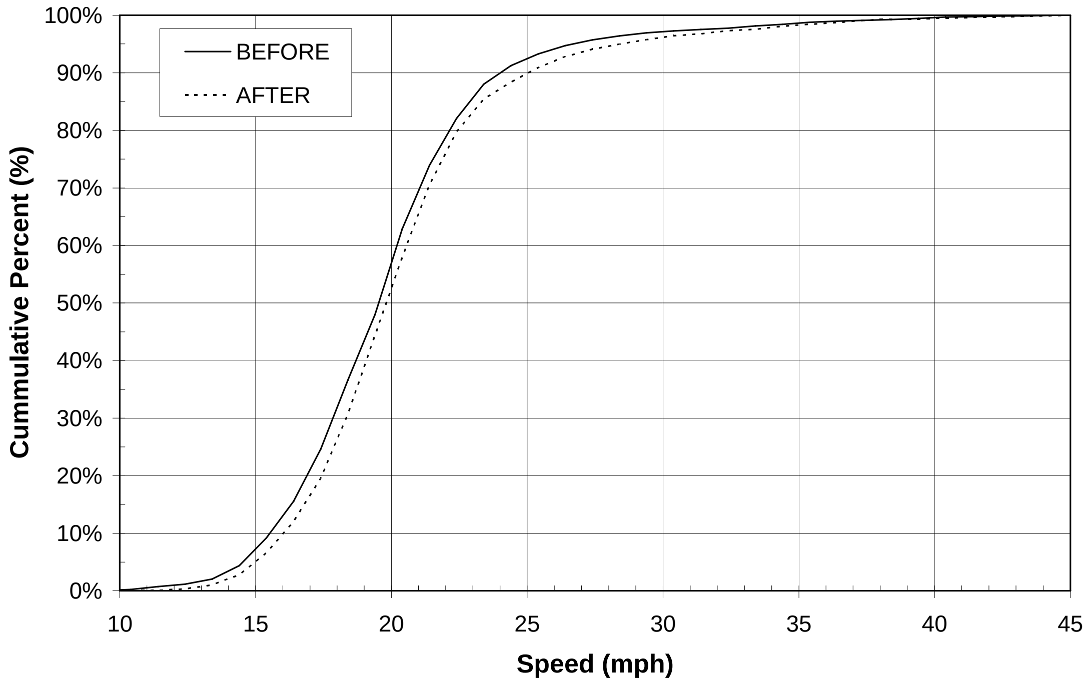


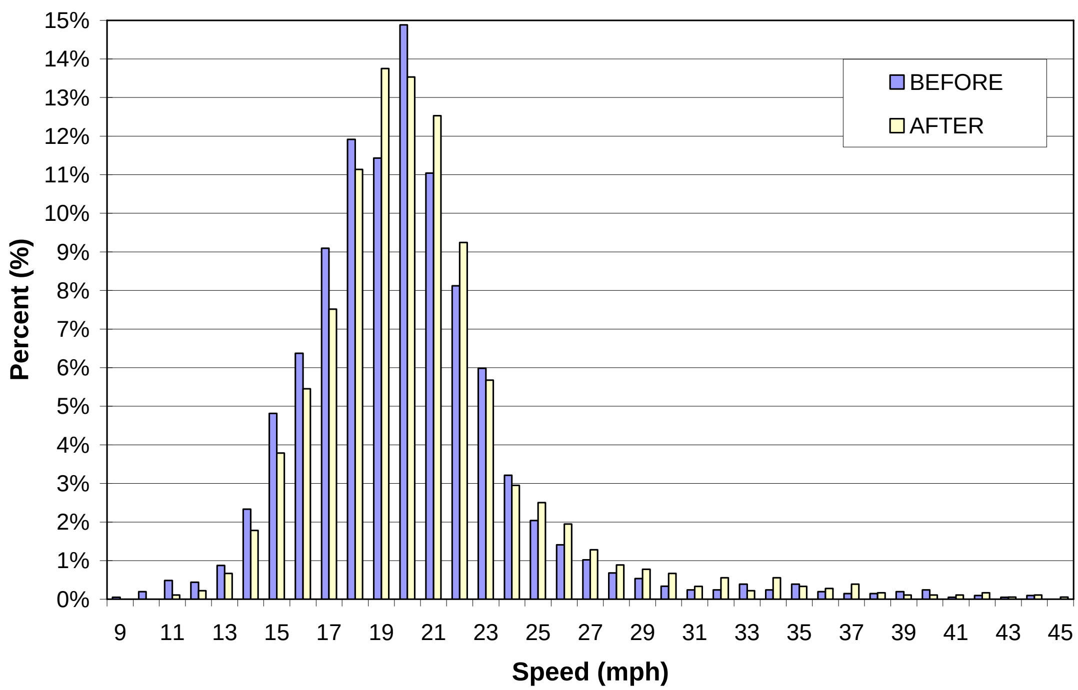


Salt Lake City Northbound Mid-Day

10:55 AM to 12:15 PM

	Before *(09/20/04 – 09/23/04)*	After *(04/04/05 – 04/07/05)*
Mean (mph)	19.85	20.39
Standard Deviation	4.14	4.29
85th Percentile (mph)	22.8	23.3
% Exceeding 20 mph	37.1%	42.0%
10 mph Pace (% in Pace)	14 – 24 (86.9%)	14 – 24 (85.6%)
Sample Size	2056	1796

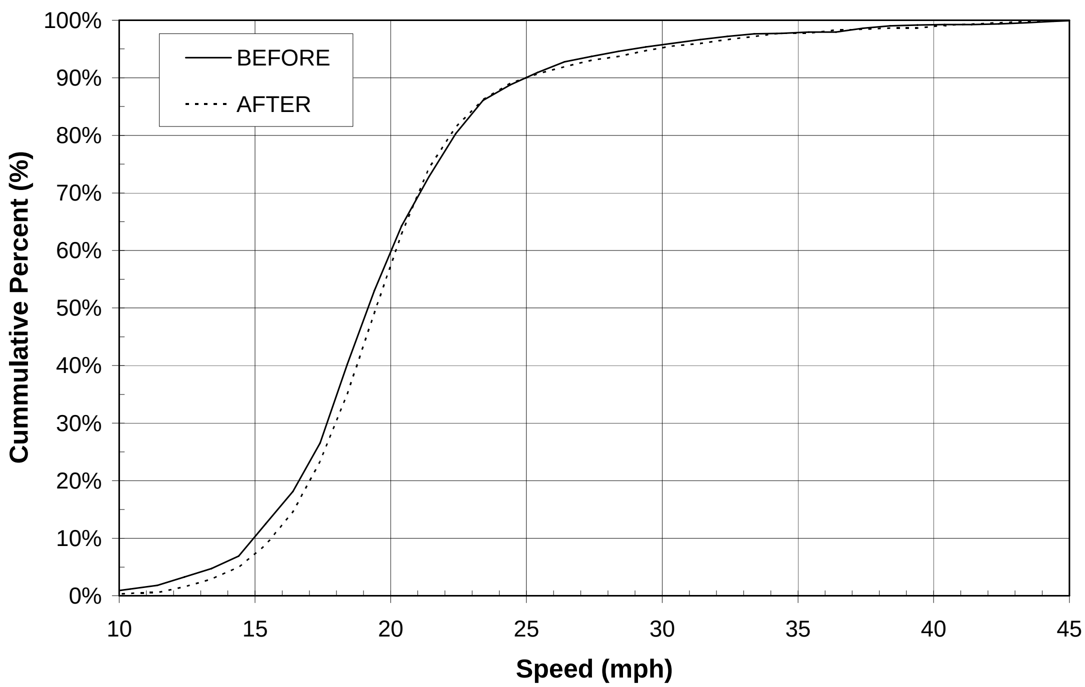


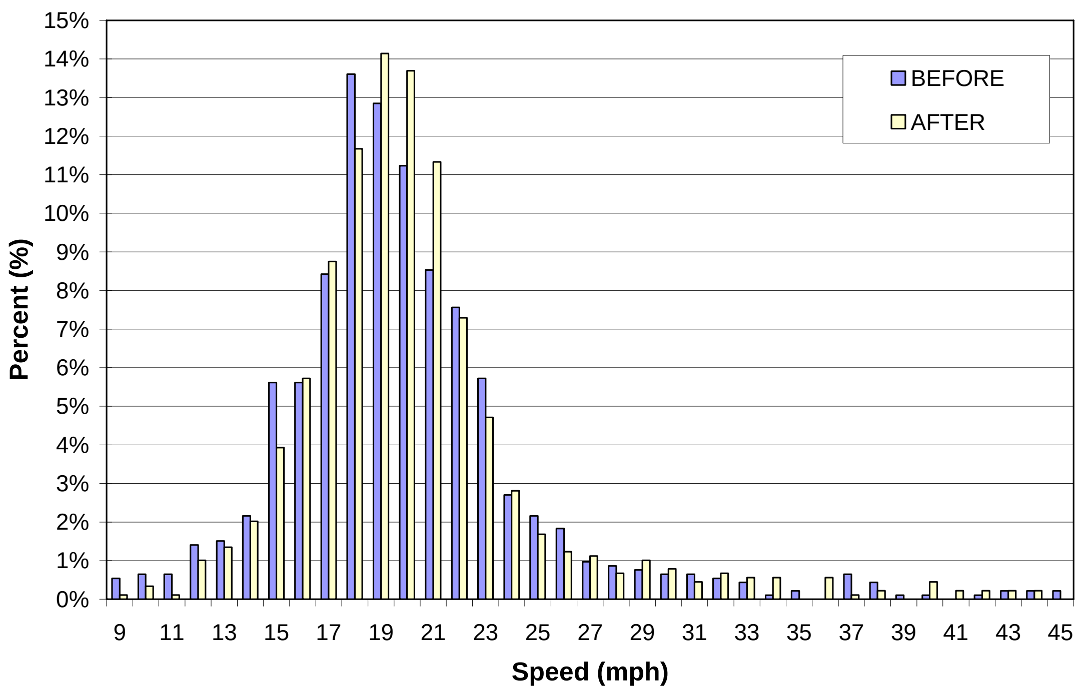


Salt Lake City Northbound Afternoon

2:30 PM to 3:15 PM

	Before *(09/20/04 – 09/23/04)*	**After** *(04/04/05 – 04/07/05)*
Mean (mph)	19.82	20.15
Standard Deviation	4.90	4.77
85th Percentile (mph)	23.2	22.9
% Exceeding 20 mph	35.7%	37.1%
10 mph Pace (% in Pace)	14 – 24 (81.9%)	14 – 24 (84.1%)
Sample Size	926	891

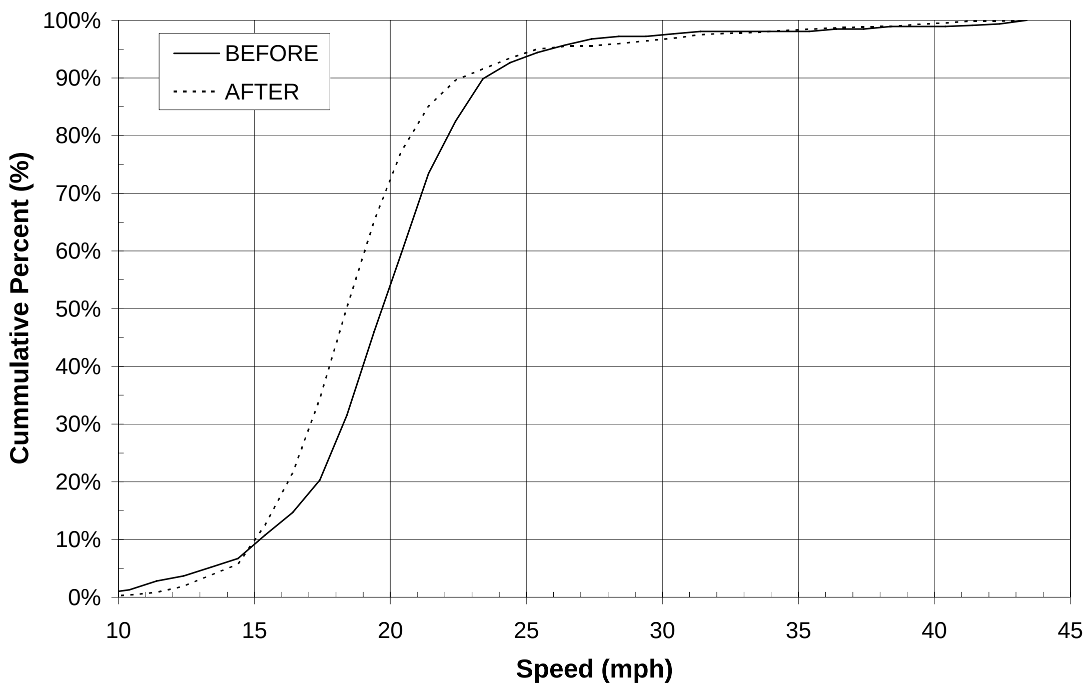


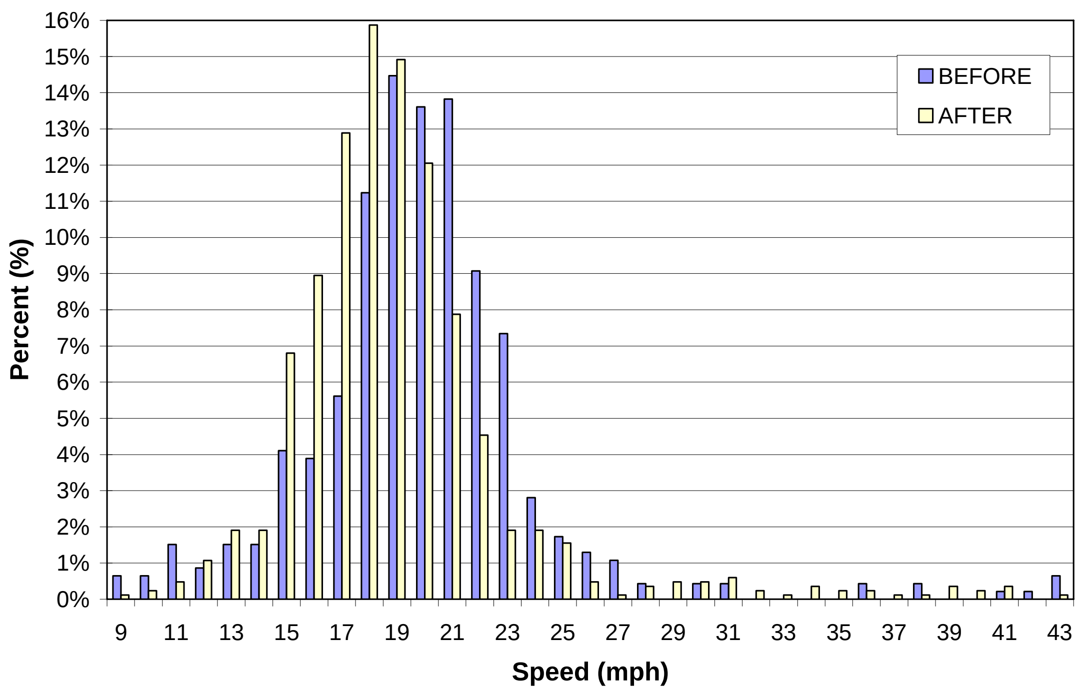


Salt Lake City Southbound Morning

7:30 AM to 8:25 AM

	Before *(09/20/04 – 09/23/04)*	After *(04/04/05 – 04/07/05)*
Mean (mph)	19.83	18.94
Standard Deviation	4.36	4.23
85th Percentile (mph)	22.7	21.3
% Exceeding 20 mph	40.4%	22.8%
10 mph Pace (% in Pace)	14 – 24 (86.0%)	13 – 23 (87.7%)
Sample Size	463	838

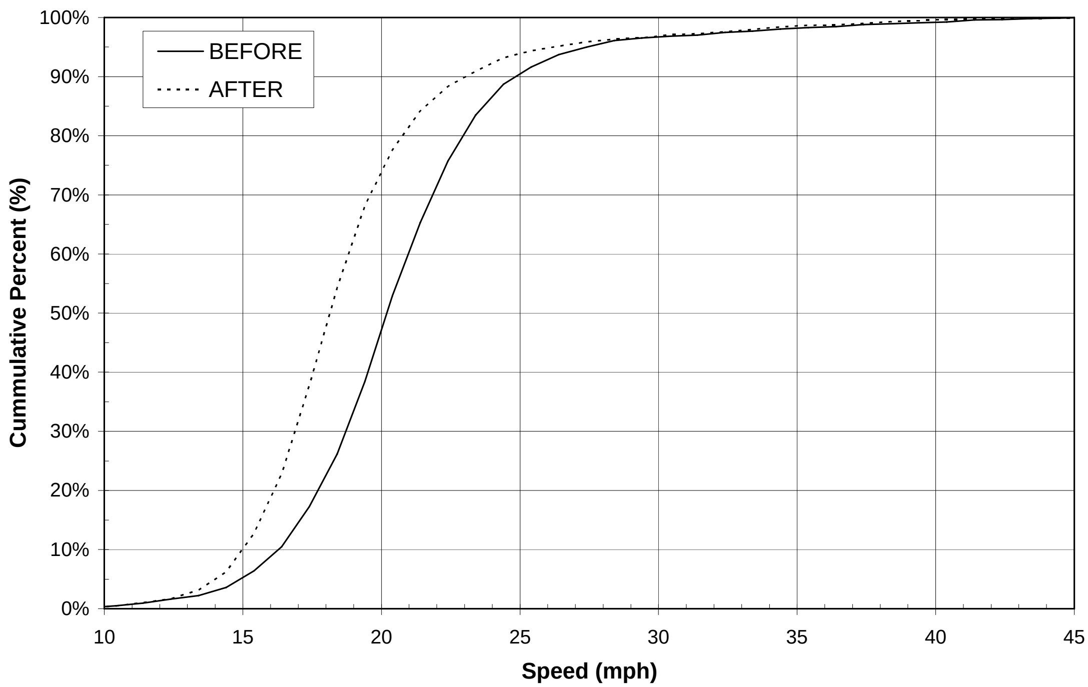


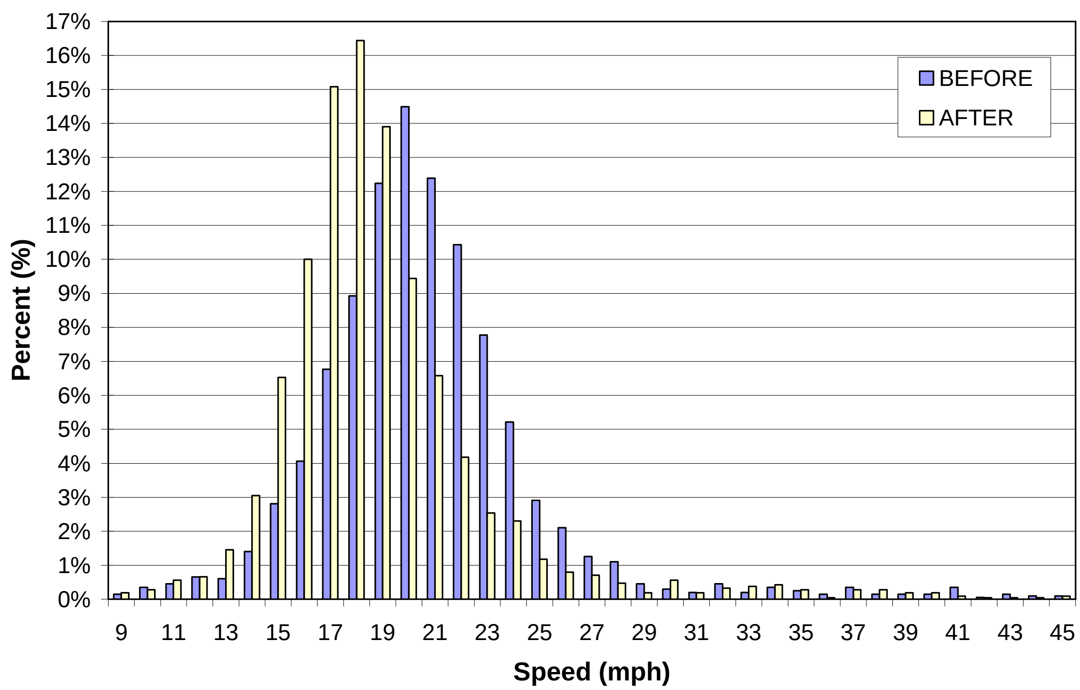


Salt Lake City Southbound Mid-Day

10:55 AM to 12:15 PM

	Before *(09/20/04 – 09/23/04)*	After *(04/04/05 – 04/07/05)*
Mean (mph)	20.61	18.84
Standard Deviation	4.32	4.24
85th Percentile (mph)	23.6	21.5
% Exceeding 20 mph	47.1%	22.4%
10 mph Pace (% in Pace)	15 – 25 (85.2%)	13 – 23 (87.7%)
Sample Size	1994	2129

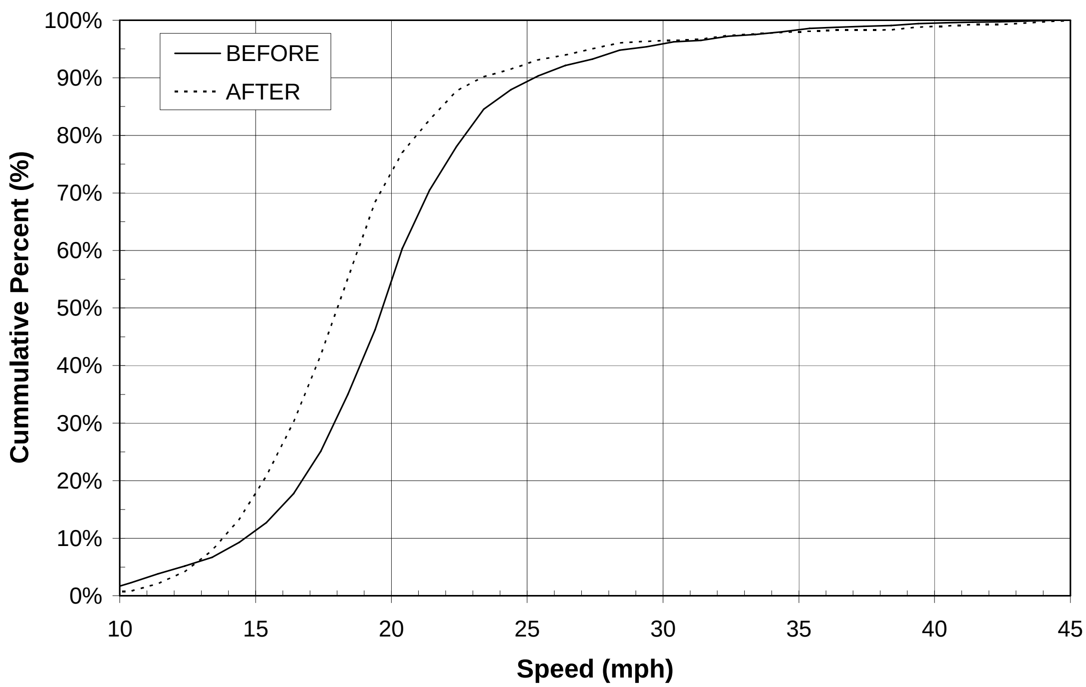


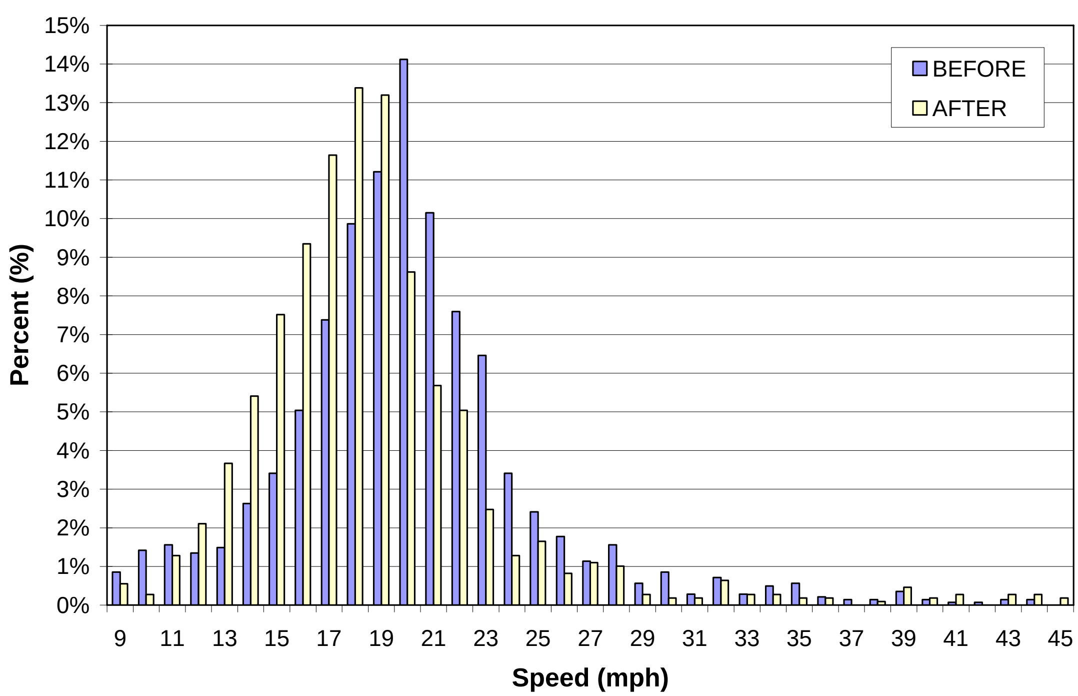


Salt Lake City Southbound Afternoon

2:30 PM to 3:15 PM

	Before *(09/20/04 – 09/23/04)*	After *(04/04/05 – 04/07/05)*
Mean (mph)	19.95	18.65
Standard Deviation	4.90	4.96
85th Percentile (mph)	23.5	21.8
% Exceeding 20 mph	39.7%	23.0%
10 mph Pace (% in Pace)	14 – 24 (78.6%)	12 – 22 (83.5%)
Sample Size	1409	1091



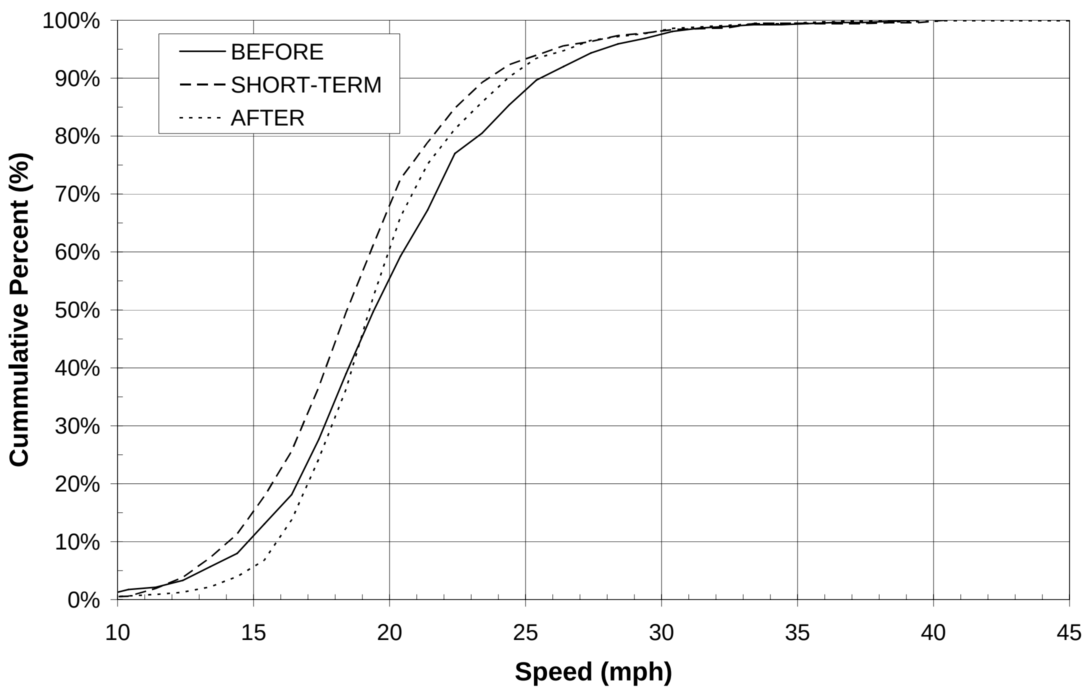


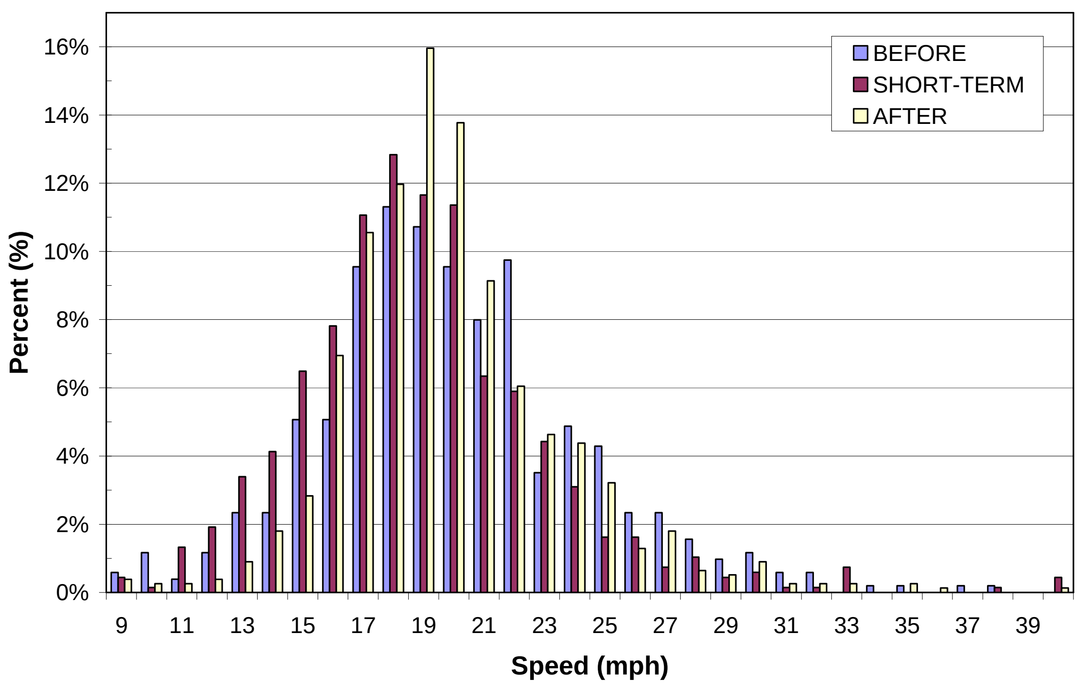
Appendix B-3. Pleasant Grove Results

Pleasant Grove Northbound Morning

8:15 AM to 8:50 AM

	Before (10/04/04 – 10/07/04)	Short-term (11/29/04 – 12/02/04)	After (03/21/05 – 03/24/05)
Mean (mph)	19.88	18.81	19.80
Standard Deviation	4.44	4.16	3.78
85th Percentile (mph)	24.2	22.4	23.3
% Exceeding 20 mph	40.7%	27.4%	34.0%
10 mph Pace (% in Pace)	14 – 24 (77.4%)	13 – 23 (82.0%)	15 – 25 (86.6%)
Sample Size	513	678	777

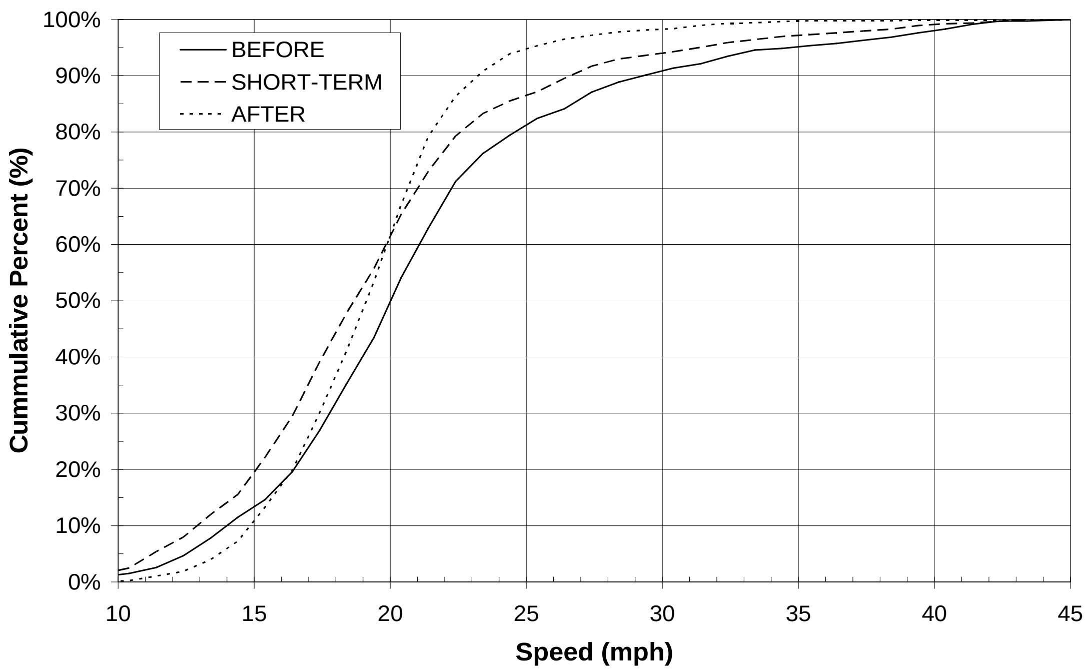


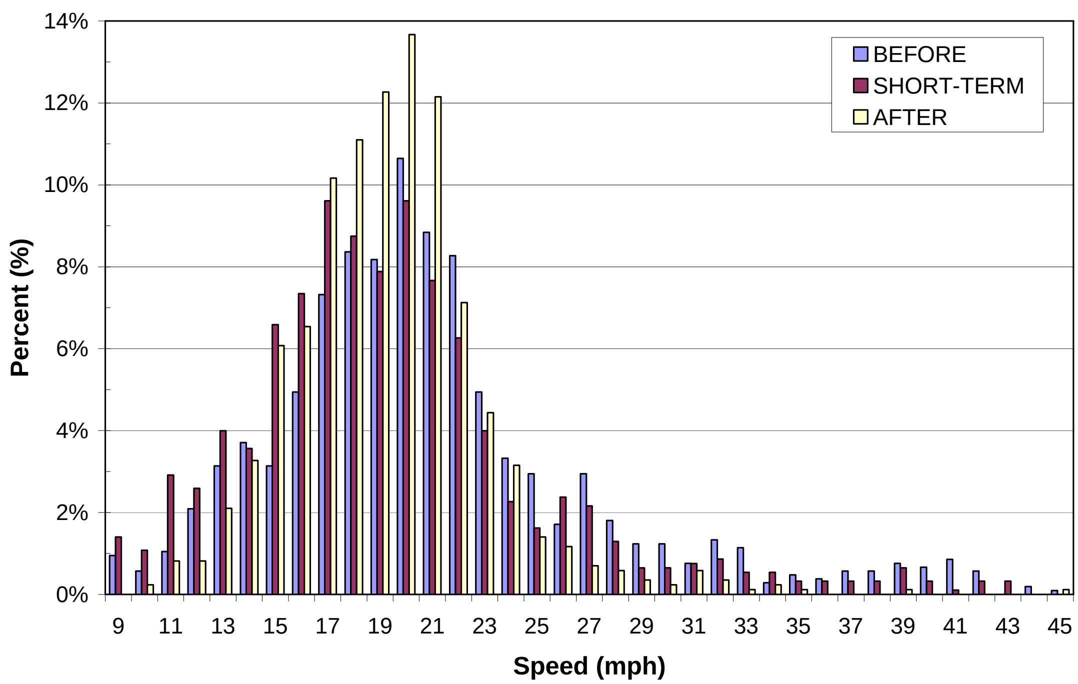


Pleasant Grove Northbound Afternoon

3:25 PM to 4:00 PM

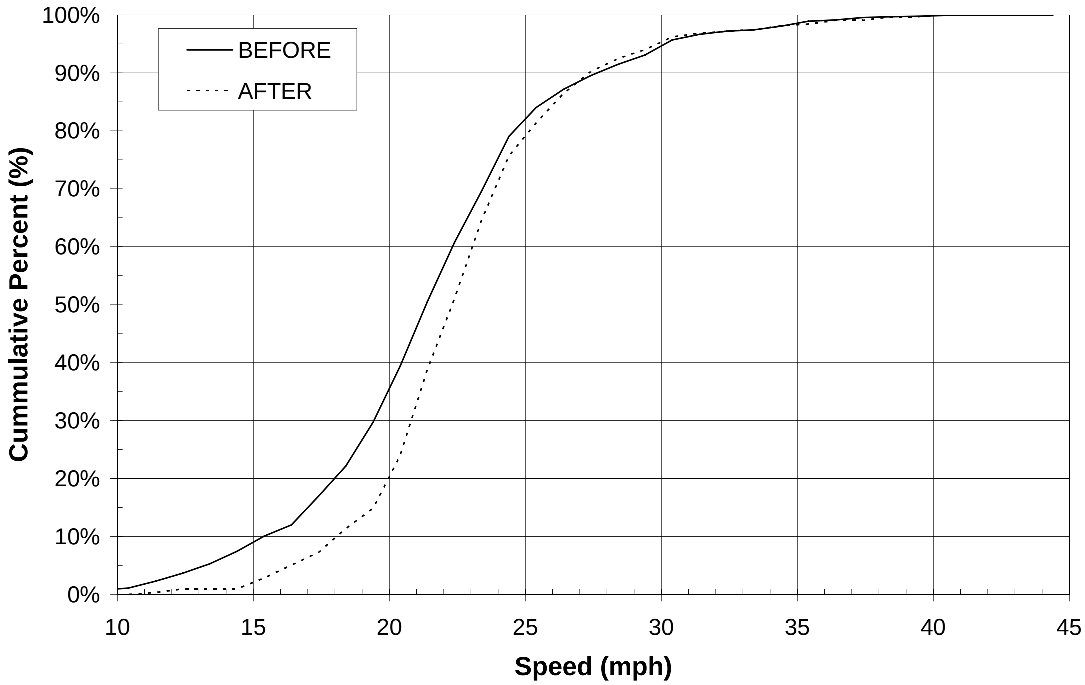
	Before (10/04/04 – 10/07/04)	Short-term (11/29/04 – 12/02/04)	After (03/21/05 – 03/24/05)
Mean (mph)	20.98	19.38	19.25
Standard Deviation	6.33	5.84	3.70
85th Percentile (mph)	26.7	24.2	22.1
% Exceeding 20 mph	45.9%	34.7%	32.9%
10 mph Pace (% in Pace)	13 – 23 (68.3%)	13 – 23 (71.3%)	13 – 23 (86.8%)
Sample Size	1052	926	856

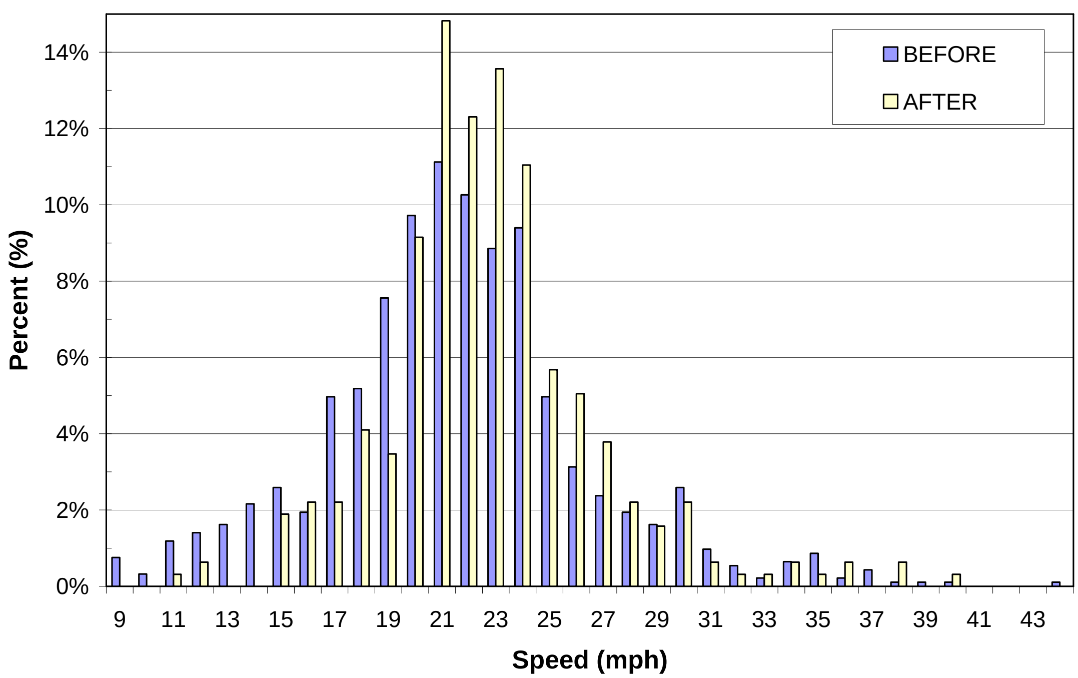




Pleasant Grove Southbound Morning
8:15 AM to 8:50 AM

	Before *(10/04/04 – 10/07/04)*	**After** *(03/21/05 – 03/24/05)*
Mean (mph)	21.58	22.69
Standard Deviation	4.92	4.09
85th Percentile (mph)	25.7	26.1
% Exceeding 20 mph	60.6%	76.0%
10 mph Pace (% in Pace)	16 – 26 (75.2%)	17 – 27 (83.0%)
Sample Size	926	317

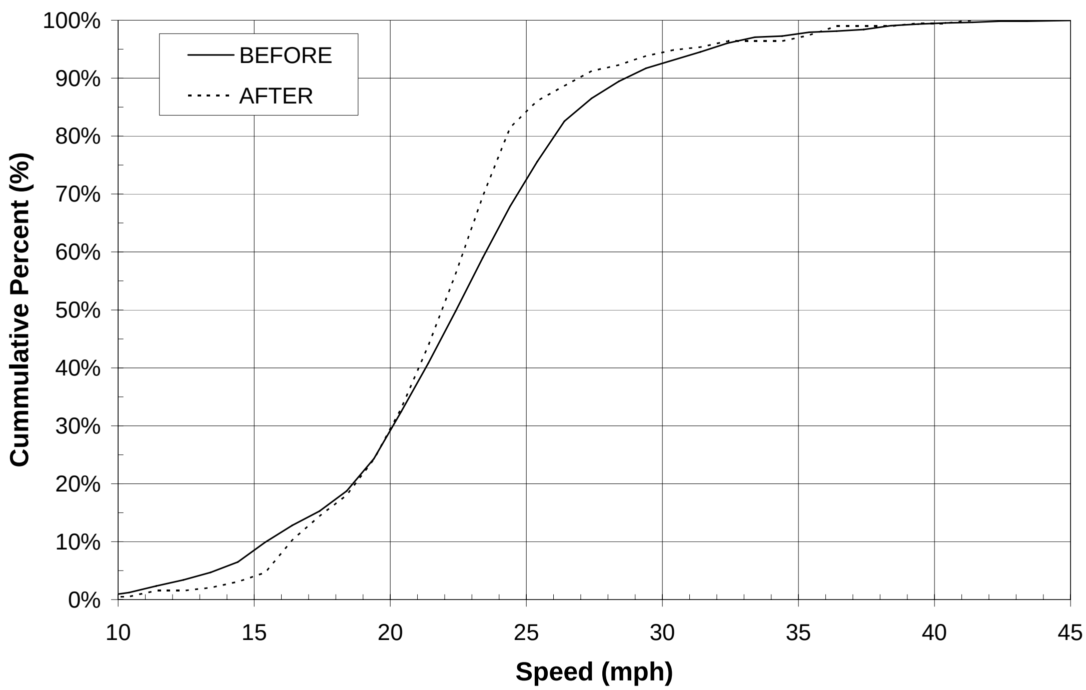


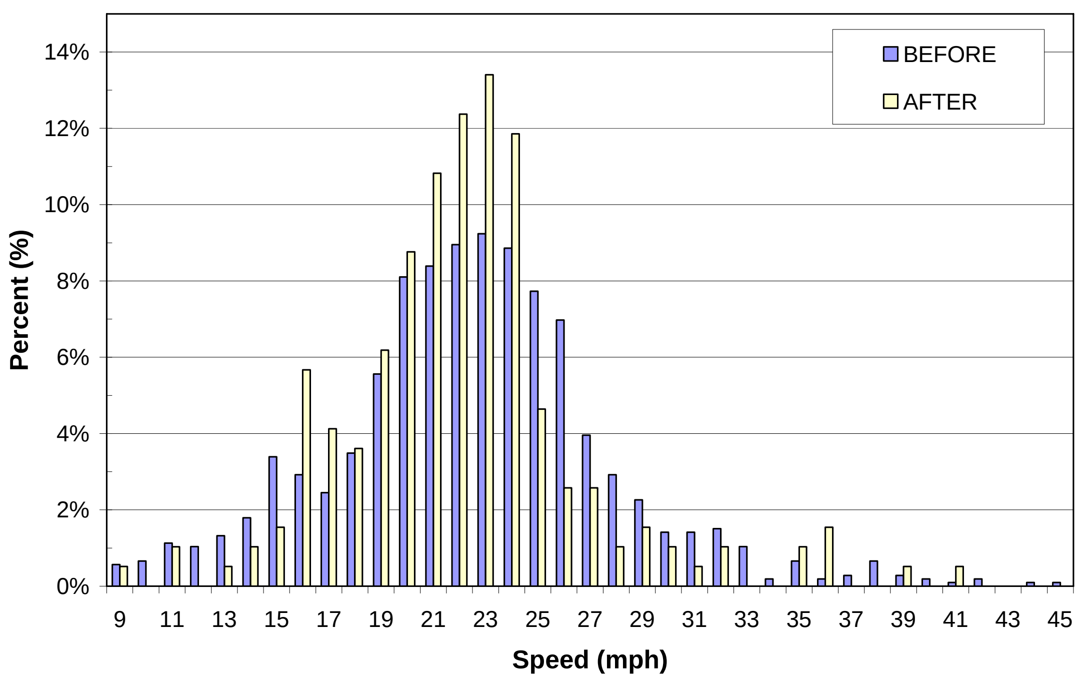


Pleasant Grove Southbound Afternoon

3:25 PM to 4:00 PM

	Before (10/04/04 – 10/07/04)	After (03/21/05 – 03/24/05)
Mean (mph)	22.49	22.04
Standard Deviation	5.37	4.72
85th Percentile (mph)	27.0	25.2
% Exceeding 20 mph	67.6%	67.0%
10 mph Pace (% in Pace)	17 – 27 (71.3%)	15 – 25 (81.4%)
Sample Size	1061	194

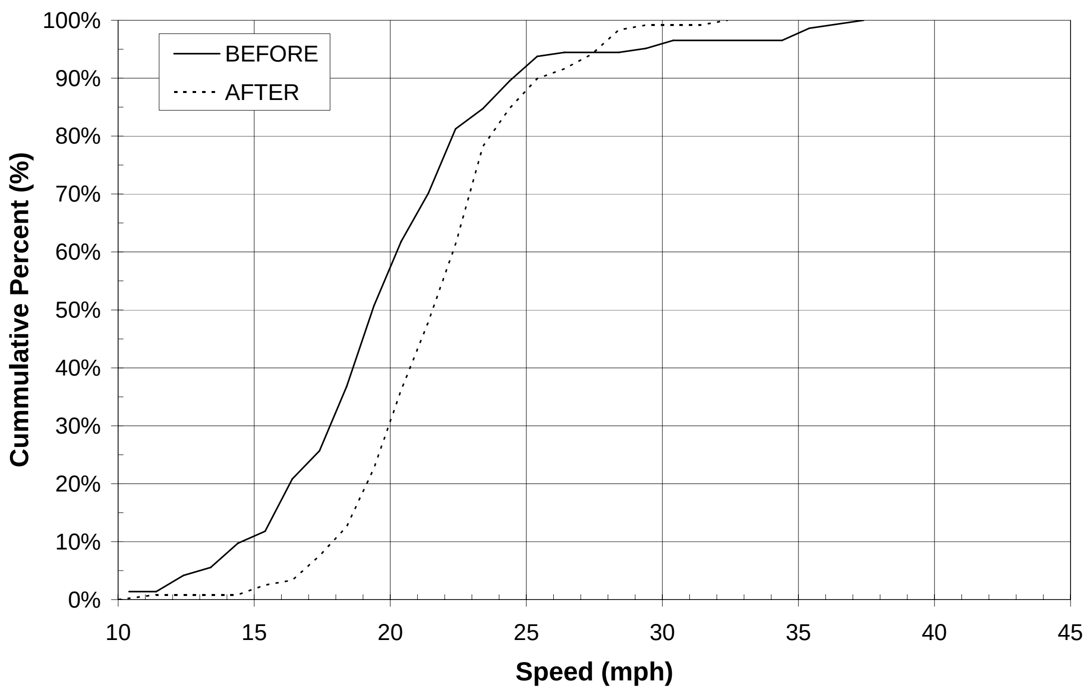


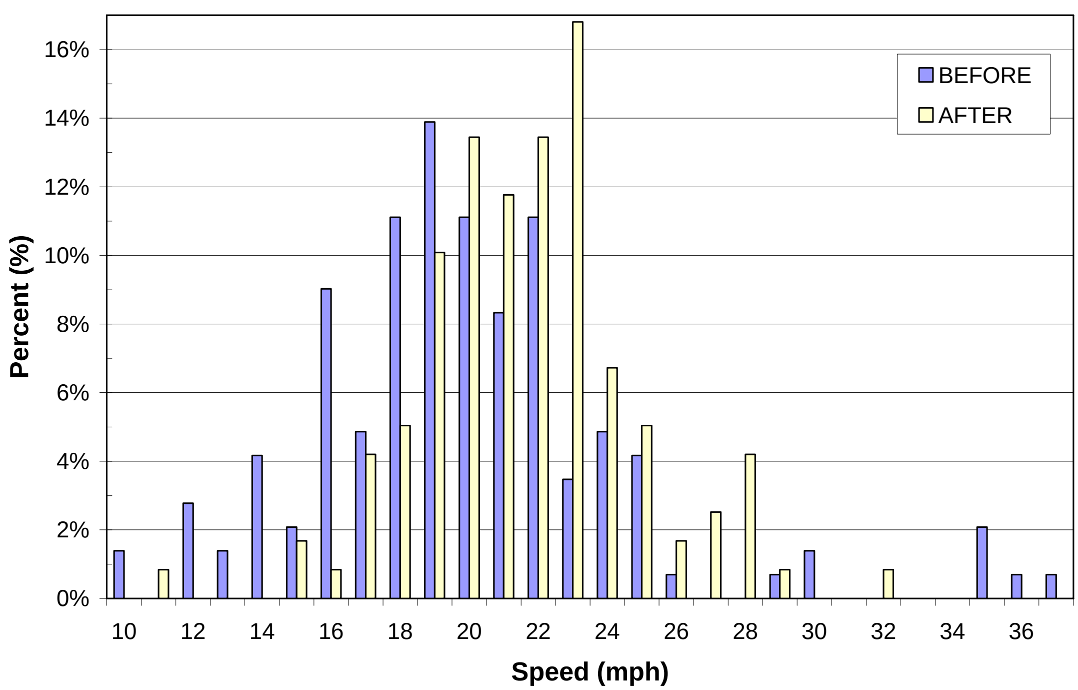


Appendix B-4. Goshen Results

Goshen Eastbound Morning
8:10 AM to 9:00 AM

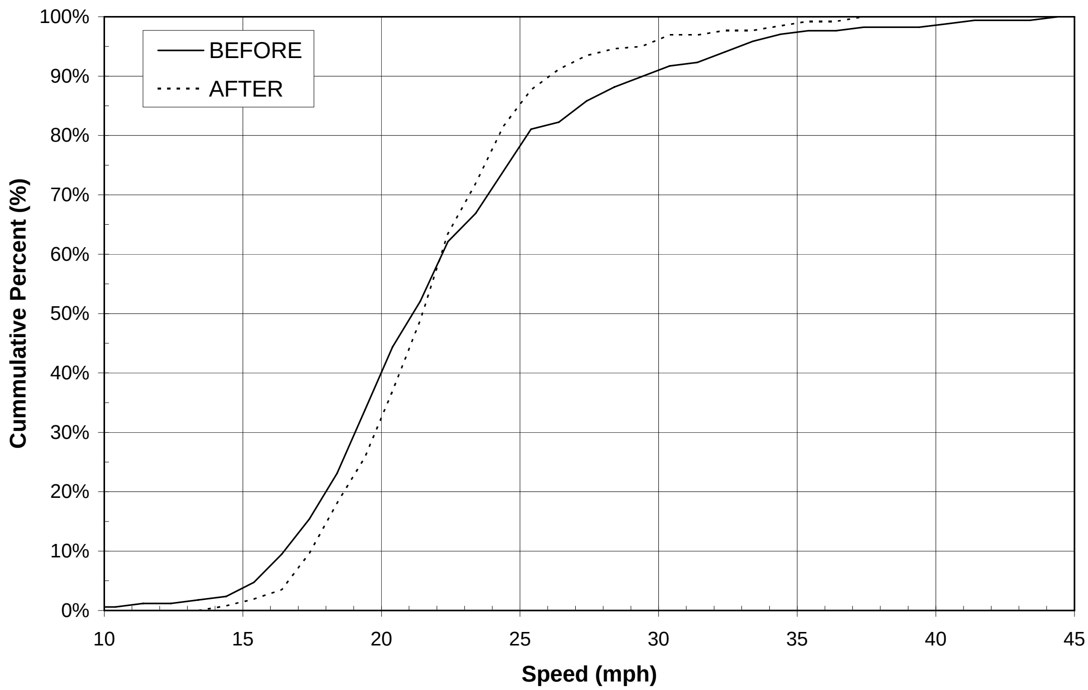
	Before *(09/27/04 – 09/30/04)*	**After** *(03/21/05 – 03/24/05)*
Mean (mph)	19.75	21.66
Standard Deviation	4.69	3.18
85th Percentile (mph)	23.4	24.4
% Exceeding 20 mph	38.2%	63.9%
10 mph Pace (% in Pace)	15 – 25 (81.9%)	16 – 26 (88.2%)
Sample Size	144	119

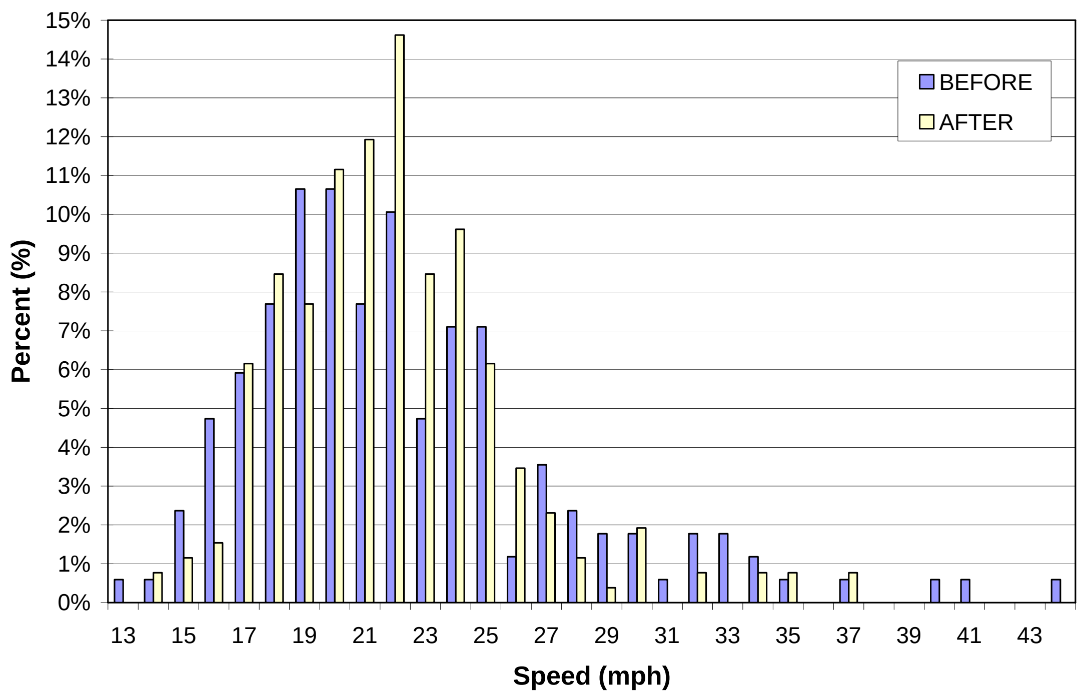




Goshen Eastbound Mid-day
11:15 to 11:45 AM and 12:10 to 12:45 PM

	Before (09/27/04 – 09/30/04)	After (03/21/05 – 03/24/05)
Mean (mph)	22.17	21.88
Standard Deviation	5.53	3.81
85th Percentile (mph)	27.0	24.9
% Exceeding 20 mph	55.6%	63.1%
10 mph Pace (% in Pace)	15 – 25 (76.3%)	16 – 26 (87.7%)
Sample Size	169	260

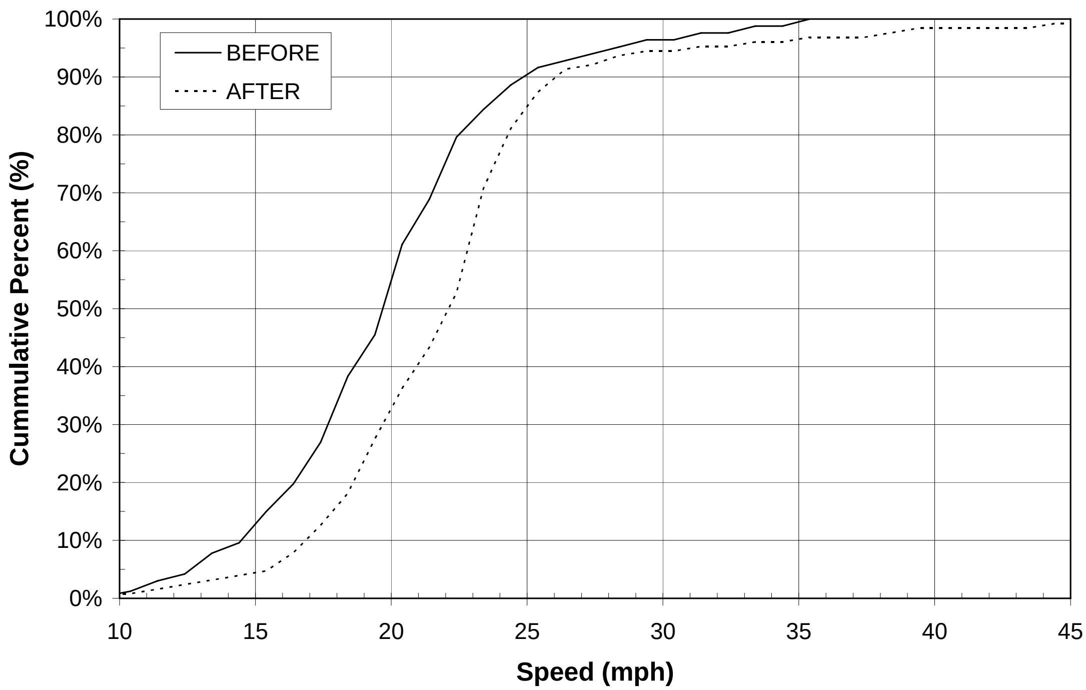


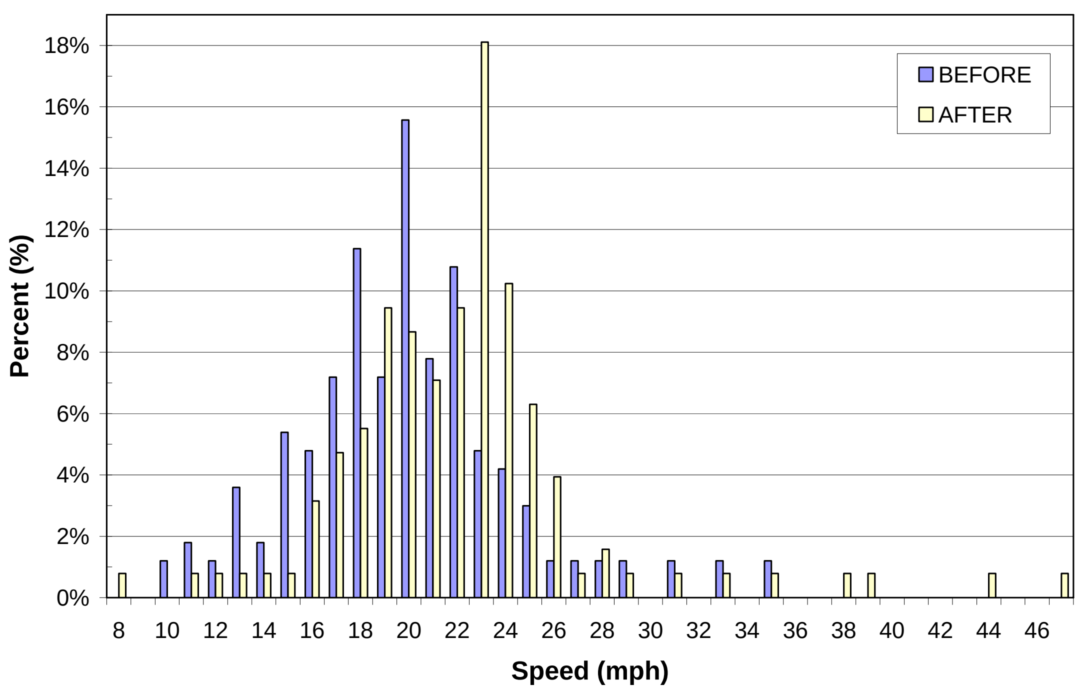


Goshen Eastbound Afternoon

2:45 to 3:20 PM

	Before *(09/27/04 – 09/30/04)*	After *(03/21/05 – 03/24/05)*
Mean (mph)	19.72	22.05
Standard Deviation	4.48	5.27
85th Percentile (mph)	23.5	24.9
% Exceeding 20 mph	38.9%	63.8%
10 mph Pace (% in Pace)	14 – 24 (79.0%)	16 – 26 (83.5%)
Sample Size	167	127

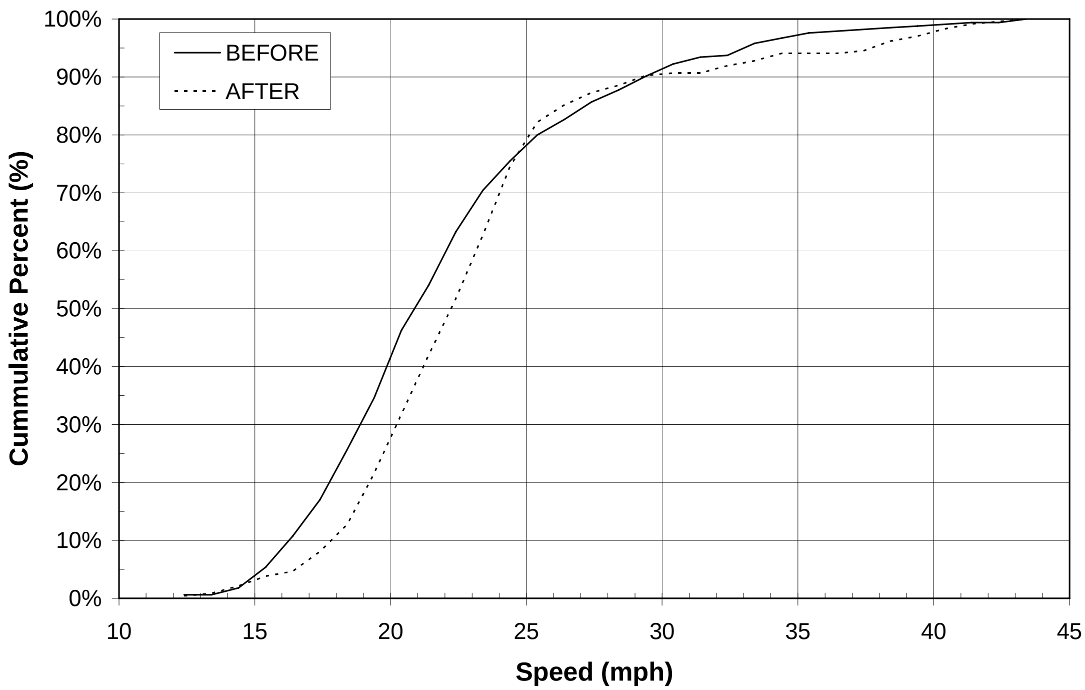


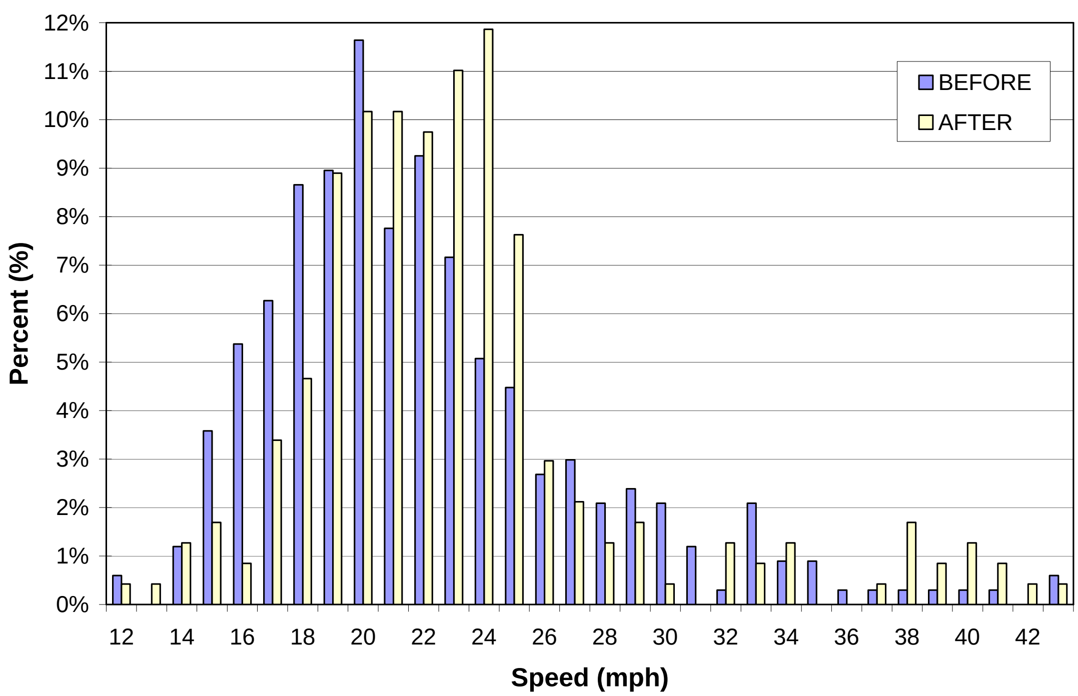


Goshen Eastbound Late-Afternoon

3:45 to 5:00 PM

	Before (09/27/04 – 09/30/04)	After (03/21/05 – 03/24/05)
Mean (mph)	22.02	23.12
Standard Deviation	5.33	5.54
85th Percentile (mph)	27.3	26.4
% Exceeding 20 mph	53.7%	68.2%
10 mph Pace (% in Pace)	15 – 25 (74.6%)	16 – 26 (80.5%)
Sample Size	335	236

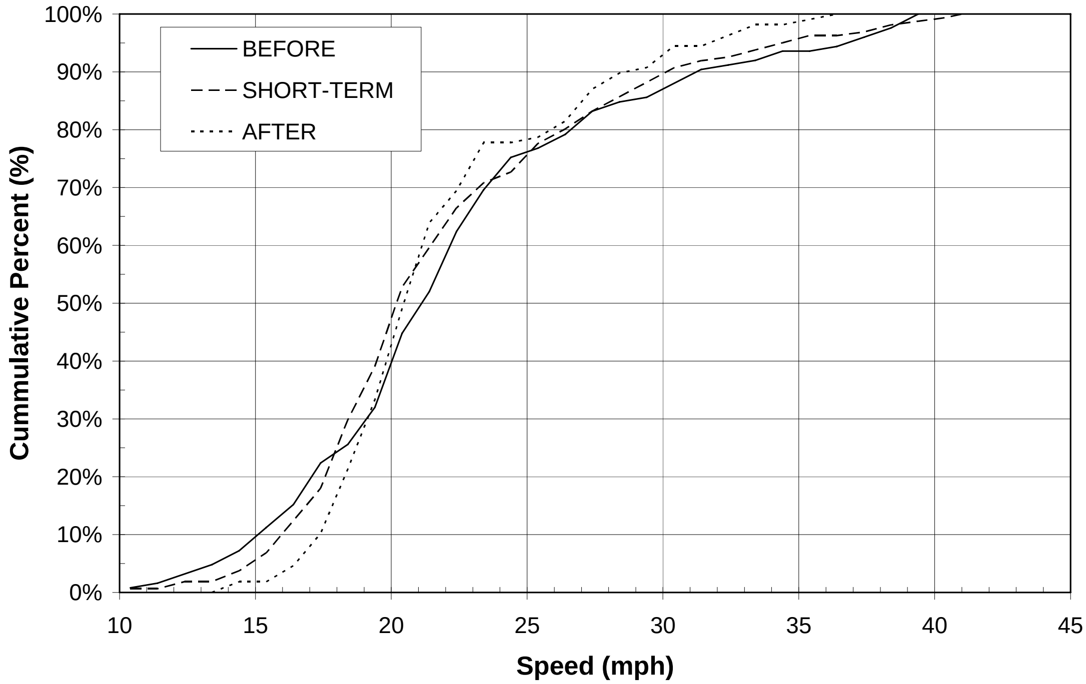


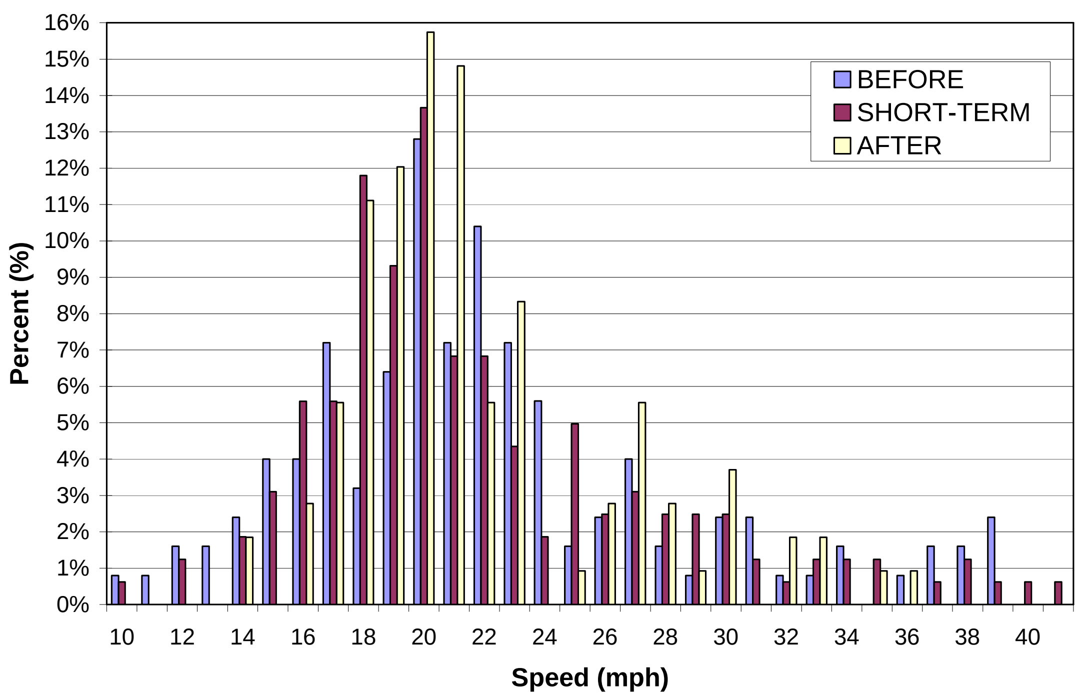


Goshen Westbound Morning

8:10 AM to 9:00 AM

	Before (09/27/04 – 09/30/04)	Short-term (11/29/04 – 12/02/04)	After (03/21/05 – 03/24/05)
Mean (mph)	22.09	21.86	21.77
Standard Deviation	6.36	5.93	4.56
85th Percentile (mph)	28.3	27.8	27.3
% Exceeding 20 mph	55.2%	47.2%	50.9%
10 mph Pace (% in Pace)	14 – 24 (68.0%)	15 – 25 (70.8%)	16 – 26 (76.9%)
Sample Size	125	161	108

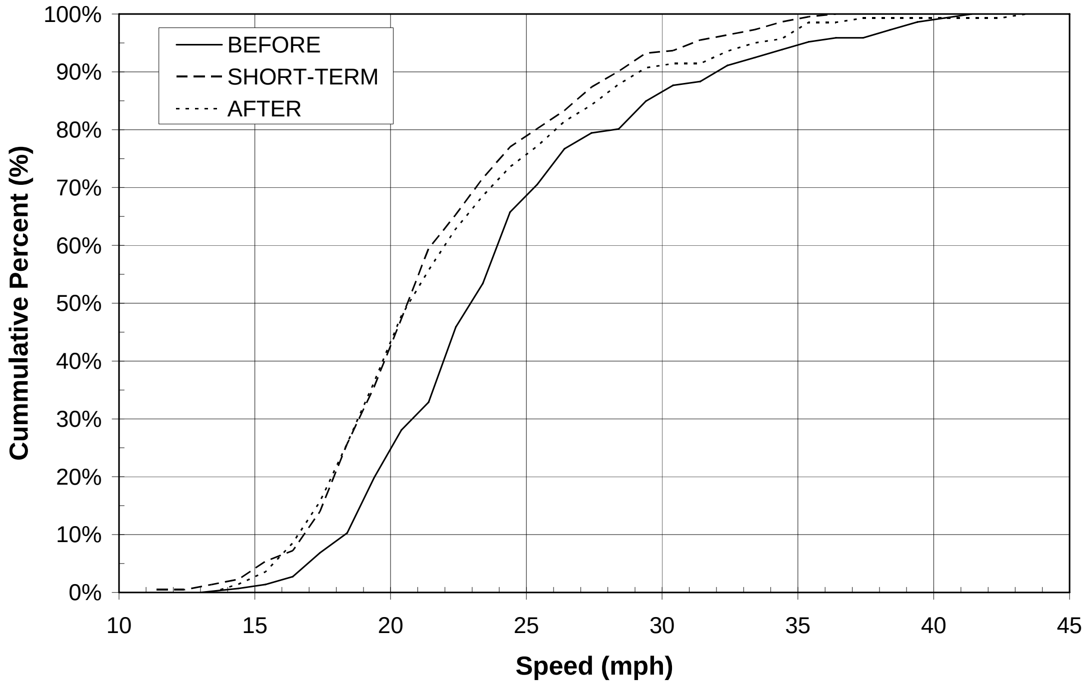


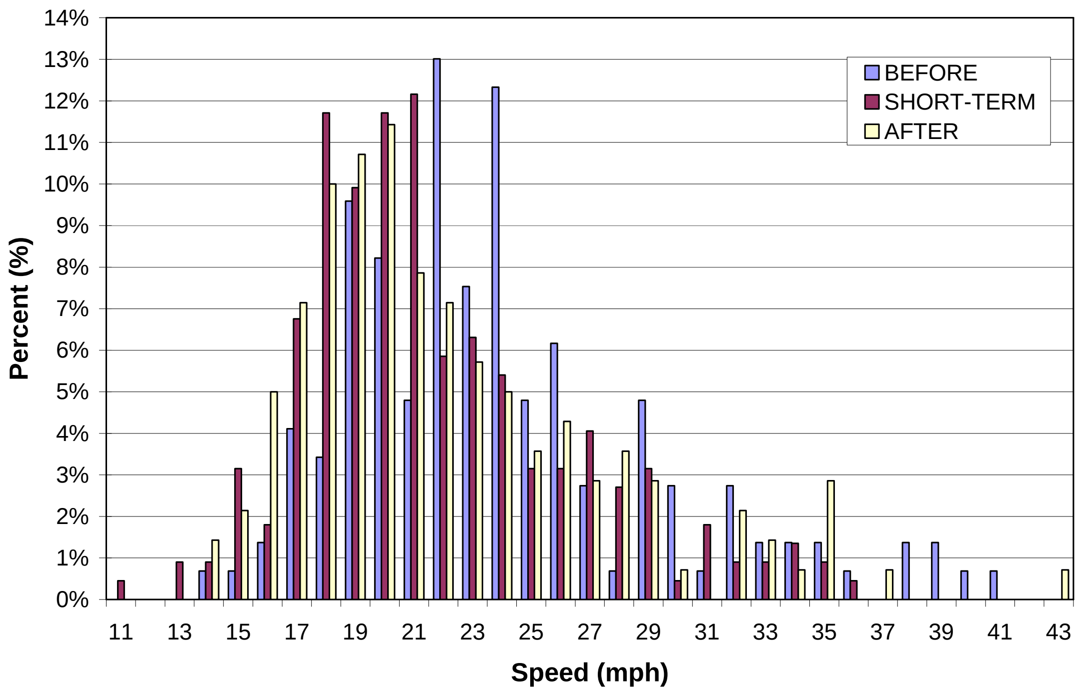


Goshen Westbound Mid-day

11:15 to 11:45 AM and 12:10 to 12:45 PM

	Before (09/27/04 – 09/30/04)	Short-term (11/29/04 – 12/02/04)	After (03/21/05 – 03/24/05)
Mean (mph)	23.99	21.56	22.17
Standard Deviation	5.47	4.66	5.29
85th Percentile (mph)	29.4	26.5	27.5
% Exceeding 20 mph	71.9%	52.7%	52.1%
10 mph Pace (% in Pace)	16 – 26 (74.0%)	16 – 26 (76.1%)	15 – 25 (73.6%)
Sample Size	146	222	140

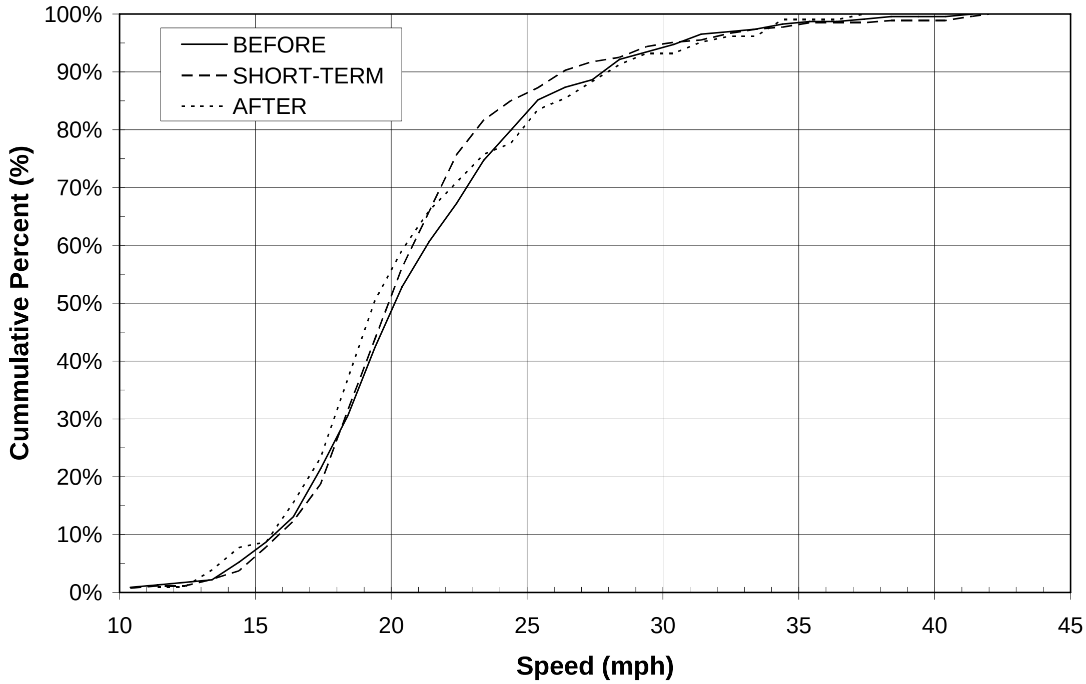


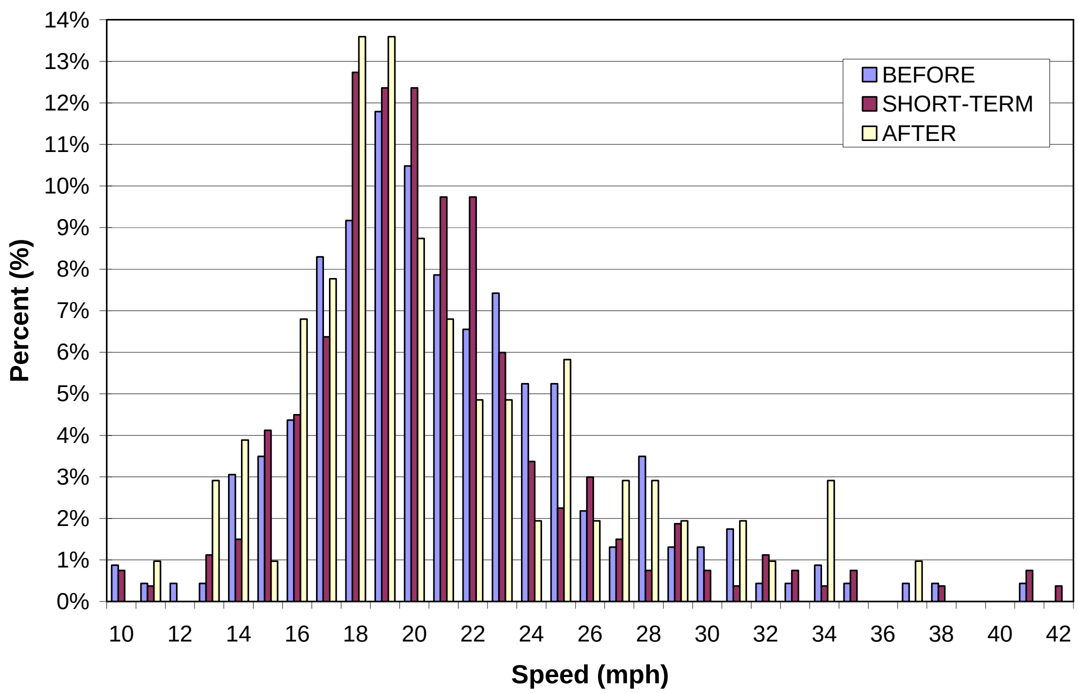


Goshen Westbound Afternoon

2:45 to 3:20 PM

	Before (09/27/04 – 09/30/04)	Short-term (11/29/04 – 12/02/04)	After (03/21/05 – 03/24/05)
Mean (mph)	20.96	20.68	20.79
Standard Deviation	4.94	4.81	5.04
85th Percentile (mph)	25.3	24.3	25.8
% Exceeding 20 mph	47.2%	43.8%	40.8%
10 mph Pace (% in Pace)	15 – 25 (76.4%)	14 – 24 (81.3%)	15 – 25 (74.8%)
Sample Size	229	267	103





Goshen Westbound Late-Afternoon

3:45 to 5:00 PM

	Before *(09/27/04 – 09/30/04)*	Short-term *(11/29/04 – 12/02/04)*	After *(03/21/05 – 03/24/05)*
Mean (mph)	21.61	20.73	21.49
Standard Deviation	5.09	4.60	4.75
85th Percentile (mph)	25.9	24.8	26.3
% Exceeding 20 mph	53.2%	43.3%	50.0%
10 mph Pace (% in Pace)	16 – 26 (77.3%)	14 – 24 (81.3%)	16 – 26 (79.3%)
Sample Size	295	374	92